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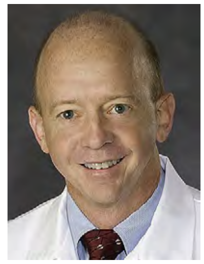
Atlas of the Oral and Maxillofacial Surgery Clinics

Preface

Current Concepts in Temporomandibular Joint Surgery



Gregory M. Ness, DDS
Guest Editor

The oral and maxillofacial surgery world is experiencing a resurgence of interest in temporomandibular joint disease and its surgical treatment, and this issue will be a valuable aid to those surgeons in training, or in practice, who wish to better understand contemporary operations performed on the temporomandibular joint. If you care to know why this is so, you may read on.

It is customary to recognize the article authors as experts in the field, but in this case it would be an understatement: the senior authors are truly a cross-section of the top temporomandibular joint surgeons in the world today. All are members of the American or European Societies of Temporomandibular Joint Surgeons, two institutions devoted to the exchange and advancement of knowledge in this field. It is my great honor to know these surgeons and scholars personally, and I am deeply grateful to each of them for their willingness to share their knowledge, not to mention their beautiful images, in this text. Furthermore, while the typical practice in the *Atlas of the Oral and Maxillofacial Surgery Clinics of North America* series is to provide a list of Additional Readings at the end of each article, several of these excellent authorities possess such deep knowledge and scholarship that they have instead annotated their articles with formal references. We have chosen to retain this format in selected articles, where the outstanding illustrations one would expect from the *Atlas* are further strengthened by their foundation upon scientific citations. The astute reader will examine these references and allow them to enhance their understanding and interpretation of the author's work.

I am indebted to the senior editors and publishers of the *Atlas* series for recognizing the need for a current surgical atlas of temporomandibular joint operations, and especially to Rich Haug, who entrusted the project to me. John Vassallo at Elsevier has been a terrific help and guide who can even sound patient and encouraging electronically by e-mail. My own article was made complete by its intraoperative photographs, through the work of Allen Jones, a spectacularly gifted photographer at Virginia Commonwealth University. And without a doubt, I am blessed to have a large, wonderful, and supportive family, the chief of which is amazing and encouraging Sara, my wife. I cannot describe her without resorting to platitudes, and yet they would all be true. If I had a throne, she would be the power behind it! I love my work, but I love her much more.

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Atlas of the
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Arthroscopic Anatomy and Lysis and Lavage of the Temporomandibular Joint

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Internal derangement of the temporomandibular joint (TMJ) is one of the most common temporomandibular disorders. In 1983, Dolwick defined it as an abnormal relation between the temporomandibular disc with respect to the mandibular condyle, the temporal fossa, and the temporal eminence of the TMJ. Anterior disc displacement, with or without reduction, perforation of the retrodiscal tissue or the articular disc, and degenerative changes of the disc and/or the joint surfaces, may be present. Clinically, it may be accompanied by pain, limitation of mouth opening, clicking, and locking. In 1989, Wilkes first established a classification to correlate clinical and radiological signs with surgical findings. The Wilkes classification consists of 5 stages based on clinical, radiologic, and intraoperative findings, varying from a slight forward displacement with symptom-free normal joints to degenerative arthritic changes with severe clinical symptoms. In 1992, with the advent of minimally invasive surgical approaches, Bronstein correlated Wilkes stages with arthroscopic findings.

Different alternatives have been proposed to treat this entity, beginning with conservative approaches. Occlusal splint therapy, medical treatment based on nonsteroidal anti-inflammatory drugs (NSAIDs) and muscle relaxants, and physical treatment are the most common options among conservative methods. Those refractory cases in which no effective improvement in terms of pain and mandibular function is obtained are amenable to further surgical treatment, such as arthroscopic lysis and lavage (ALL) of the superior joint space.

In 1975, Onishi first used an arthroscope in Japan to treat dysfunction of the human TMJ. ALL is the simplest and the most frequently used arthroscopic technique. The term lysis was first used by Sanders in 1986, meaning to sweep with a blunt probe to eliminate the suction cup effect of the disc to the fossa and to lyse adhesions. The technique consists on performing a lysis or the breaking of adherences between the articular surfaces, lavage with abundant serum, and intraoperative mandibular movements or sweeping. In a multicentric study among most experienced centers in the United States, ALL was performed in 85% of almost 5000 arthroscopies of the TMJ.

Macroscopic anatomy of the TMJ

The TMJ is a synovial joint between the temporal bone and the mandibular condyle, which presents both superior and inferior spaces with an interposed disc between them. The superior joint space is cranially limited by an articular surface that covers the articular eminence and the mandibular fossa. Inferiorly, it is limited by the superior surface of the articular disc, and laterally and medially by the synovial membrane. The inferior joint space is limited superiorly by the inferior

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aspect of the articular disc. The disc is biconcave in shape with a length of approximately 12 mm and a width of 16 mm. It is firmly attached to the lateral and medial poles of the condyle. It is inferiorly limited by the articular surface of the mandibular condyle, and laterally and medially by the synovial membrane. The inferior joint space contains approximately 0.9 mL of synovial fluid, whereas the superior joint space contains approximately 1.2 mL. The lateral pterygoid muscle is inserted in the anteromedial aspect of the TMJ, whereas some muscular fibers insert in the fibrous connective tissue of the anterior aspect of the disc. The lateral aspect of the capsule is reinforced by the lateral ligament, whereas the medial aspect of the capsule is thin and covers a narrow area. The synovial membrane covers the entire inner surface of the TMJ. The retrodiscal tissue attachment consists of synovial cells, collagen fibers, nerves, blood vessels, and elastic fibers.

Functionally, the superior joint space is responsible for gliding or translation motion, whereas the inferior joint space is responsible for hinge opening or rotation. The shape of the synovial membrane around the disc changes during mandibular movements. The elasticity of the retrodiscal tissue and the posterior attachment of the disc allows for these movements. During maximal protrusion, the pterygoid muscle pulls the condyle and disc anteriorly while the posterior band of the disc moves anterior to the peak of the articular eminence. If the muscle contracts on the right, lateral excursion to the left is observed, and vice versa.

Arthroscopic anatomy of the TMJ

Superior Joint Space

Seven areas of the superior joint space can be examined (Fig. 1). These areas are:

1. Medial synovial drape
2. Pterygoid shadow
3. Retrodiscal synovium:
   a. Zone 1: oblique protuberance
   b. Zone 2: retrodiscal synovial tissue attached to posterior glenoid process
   c. Zone 3: lateral recess of retrodiscal synovial tissue
4. Posterior slope of articular eminence and glenoid fossa
5. Articular disc
6. Intermediate zone
7. Anterior recess:
   a. Disc synovial crease
   b. Midportion
   c. Medial-anterior corner
   d. Lateral-anterior corner.

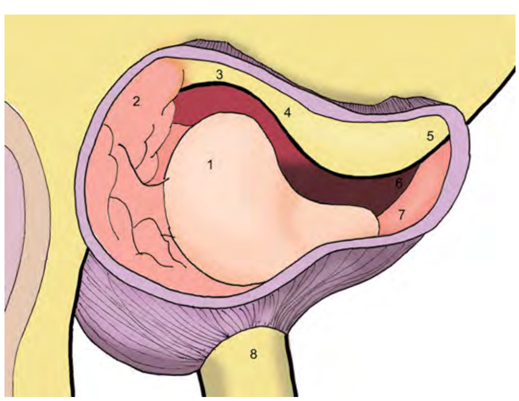

Fig. 1. Superior joint space of the TMJ. 1, Articular disc; 2, synovial lining in the posterior recess; 3, glenoid fossa; 4, posterior slope of the eminence; 5, articular eminence; 6, medial-anterior corner of the anterior recess; 7, lateral-anterior corner of the anterior recess; 8, condyle.

Four classic anatomic landmarks have been described:

1. Medial synovial drape with distinct superior-to-inferior striae
2. Oblique protuberance of the retrodiscal synovium
3. Posterior slope of the articular eminence with distinct anterior-to-posterior striae
4. Anterior disc synovial crease: juncture of anterior synovium and anterior band of disc.

The first area to be arthroscopically examined is the medial synovial drape (Fig. 2), which has a gray-white translucent lining and a tense appearance with distinct superior-to-inferior striae, which serve as the first classic anatomic landmark.

The second area to be examined is the pterygoid shadow (Fig. 3), which is located anterior to the medial synovial drape and frequently well marked. In normal situations, the pterygoid shadow has a purple appearance, because of the pterygoid muscle under the synovial lining.

The third area to be examined is the retrodiscal synovium (Fig. 4). A key point within the superior joint space is the synovial membrane with a soft appearance, located in the posterior side of the

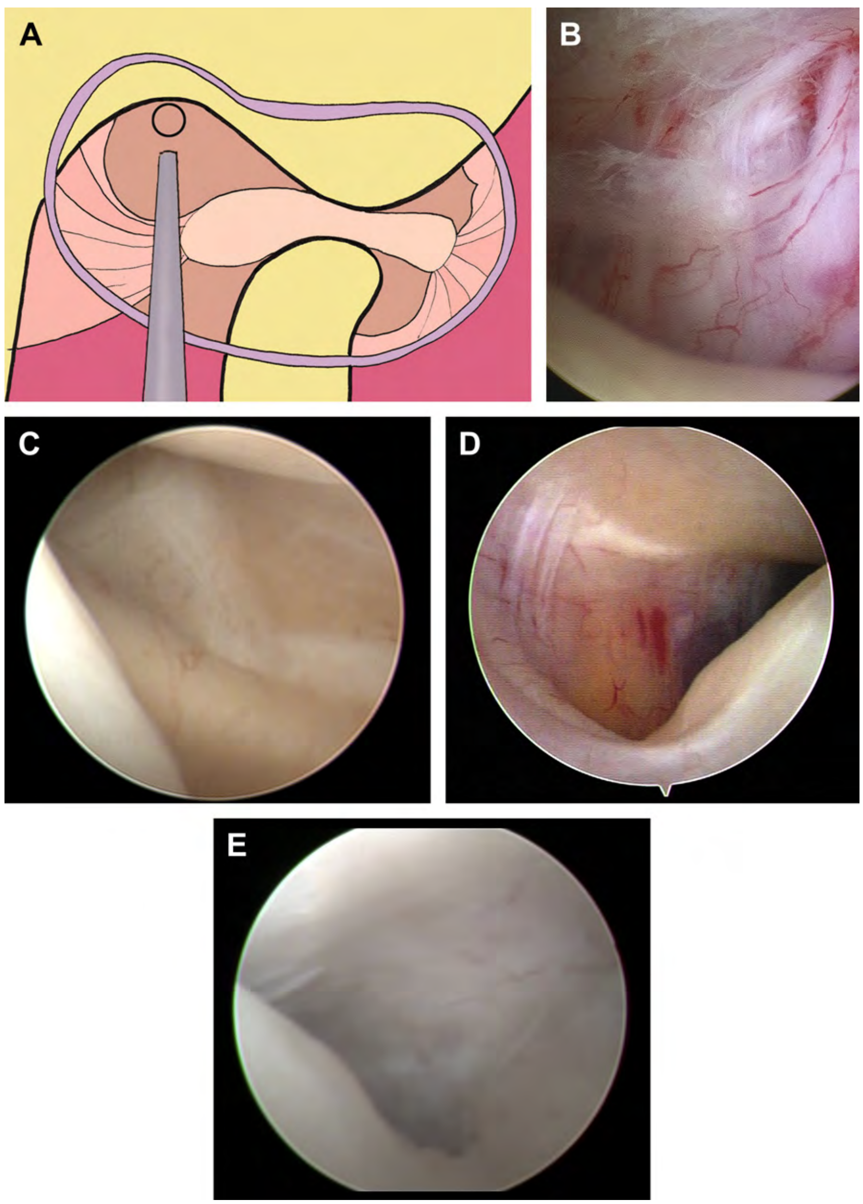

Fig. 2. Medial synovial drape. (*A*) Scheme. (*B–E*) Arthroscopic views of the medial synovial drape: (*B*) hyperemic appearance, (*C*) healthy-appearing area, (*D*) focal areas of hyperemia, (*E*) healthy-appearing area.

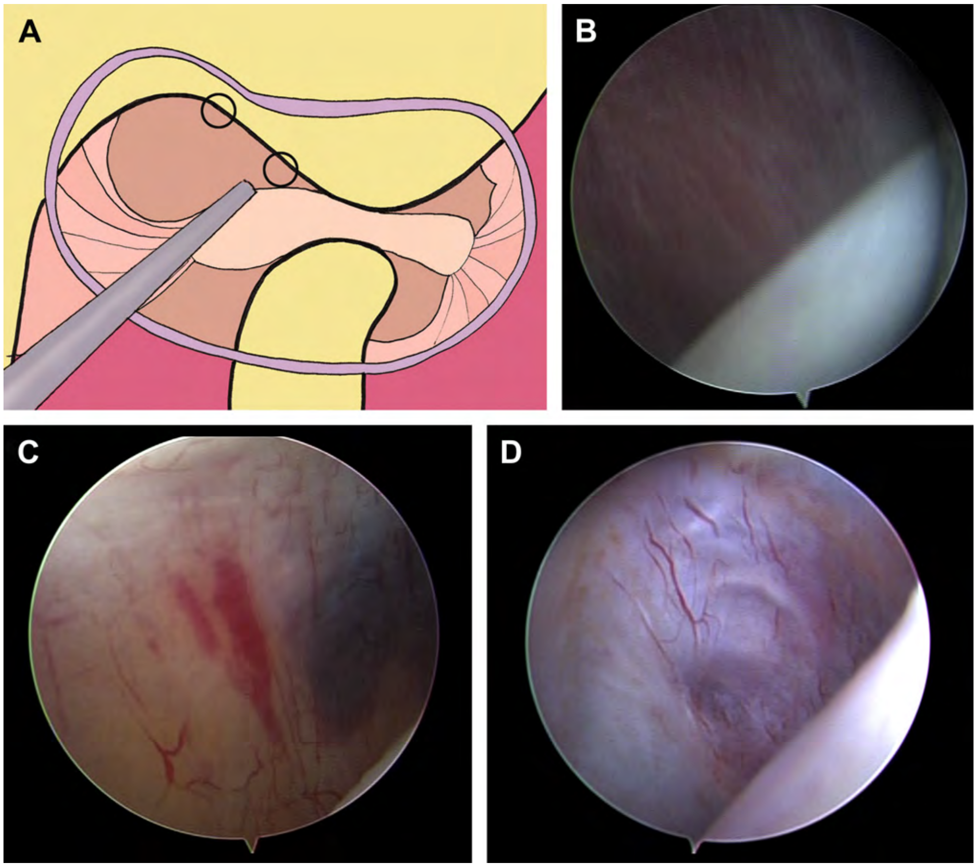

Fig. 3. Pterygoid shadow. (*A*) Scheme. (*B–D*) Arthroscopic views of the pterygoid shadow: (*B*) healthy-appearing area, (*C*) focal areas of hyperemia, (*D*) focal areas of hyperemia.

posterior synovial recess. From the lateral side, several folds on the surface of the synovial membrane appears, and they disappear as long as the disc is displaced anteriorly. The synovial membrane covers the posterior insertion of the disc and is reflected superiorly to the temporal fossa. While the mouth is open, the posterior insertion covered by the synovial lining appears as a crest or crease. This finding is named oblique protuberance. The location of the oblique protuberance is in the middle third of the retrodiscal synovium. The vascular network is observed throughout the normal synovial membrane.

The fourth area of the joint is the posterior slope of the articular eminence (Fig. 5). The fibrocartilage is white and highly reflective with anteroposterior striae. In the back slope of the eminence, the fibrocartilage is thick. Toward the glenoid fossa, the fibrocartilage becomes darker and thinner, and becomes thin without striae over the glenoid fossa.

The articular disc, which is the fifth area to be examined, is milky white, highly reflective, and without striae. In normal conditions, its surface is smooth and without fibrillations. The red-white line is the union between the posterior band of the disc and the synovium (Fig. 6A, B). From a posterolateral position of the arthroscope, the disc mobility is examined by smooth movements of the condyle forward and backward. Normally, the disc glides fluently along the articular eminence. The concept of roofing evaluates the covering of the articular disc over the condyle. Roofing is graded arthroscopically according to the posterior band of the articular disc and its position relative to the articular eminence. When it is measured with the condyle forward, the disc is in normal position (roofing 100%) if the posterior band of the disc is lying adjacent to the posterior slope of the articular eminence. With the condyle seated, it is 100% roofed if the posterior band of the disc abuts at approximately the midportion of the glenoid fossa (see Fig. 6C).

The intermediate zone is the sixth area to be examined (Fig. 7). Without disorders, this area has a white-on-white appearance and the concavity of the disc can be observed.

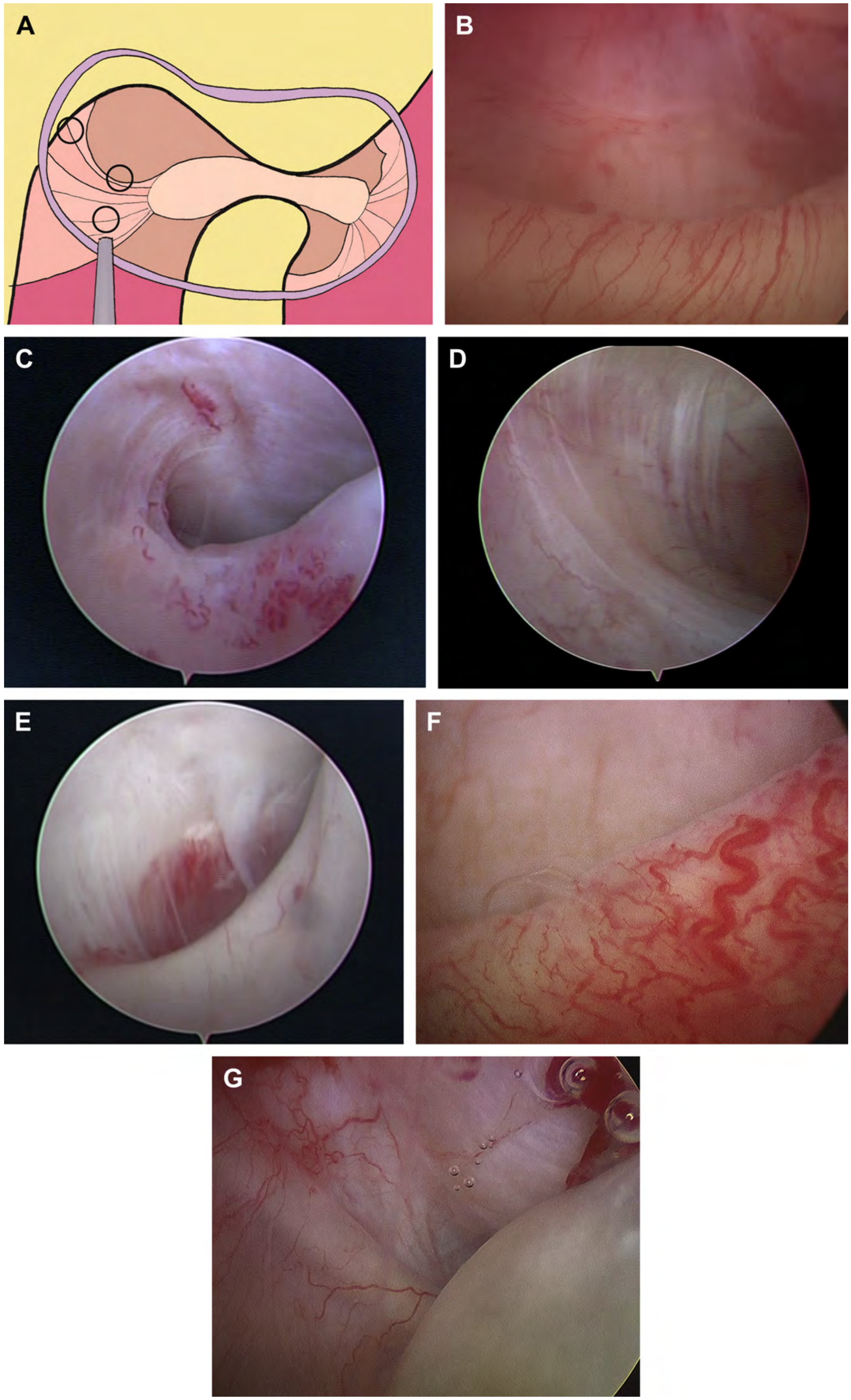

Fig. 4. Retrodiscal synovium and posterior ligament. (*A*) Scheme. (*B–G*) Arthroscopic views of the retrodiscal synovium and posterior ligament: (*B*) hyperemic appearance, (*C*) focal areas of hyperemia, (*D*) healthy-appearing area, (*E*) healthy-appearing area, (*F*) hyperemic appearance, (*G*) focal areas of hyperemia.

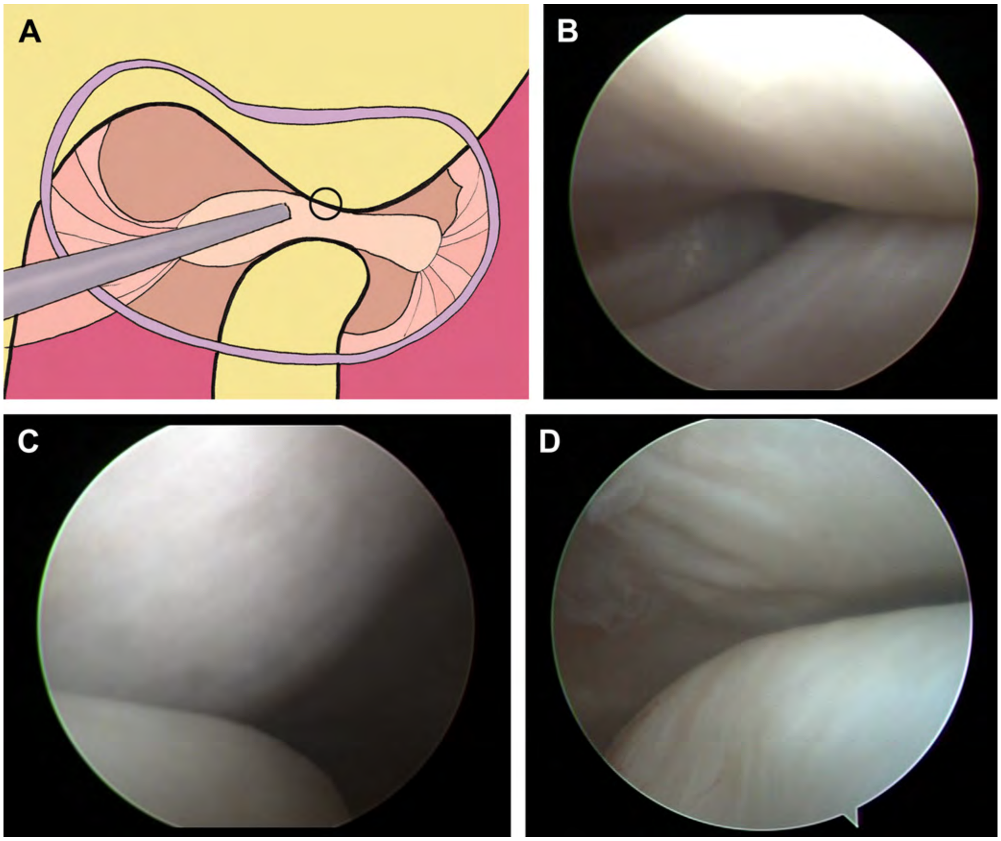

Fig. 5. Posterior slope of the articular eminence. (*A*) Scheme. (*B–D*) Arthroscopic views of the posterior slope of the articular eminence showing healthy-appearing area.

The anterior recess (Fig. 8) is the seventh area to be examined. It begins with the condyle seated. In this area, the anterior disc synovial crease, which is the fourth classic anatomic landmark, is identified. At the anterolateral site, the union between the lateral synovial capsule and the anterior disc synovial crease can be observed, and this is the ideal place for insertion of the second or working cannula.

Inferior Joint Space

The inferior joint space is not routinely explored, except when a perforation of the disc or the retrodiscal tissue exists (Fig. 9A). This space is narrow compared with the superior joint space (see Fig. 9B). The posteroinferior and anteroinferior recesses are separated by the intermediate zone formed by the condyle and the disc. The clinical significance of this space has rarely been described and thus is not discussed in this article.

Arthroscopic lysis and lavage

Indications of ALL

Before performing the surgical approach of the internal derangement of the TMJ, it is recommended to wait between 3 and 6 months after a previous conservative approach to properly identify the patient reluctant to conservative treatments. Most of the intra-articular disorders are amenable to be treated by ALL. The American Association of Oral and Maxillofacial Surgery (AAOMS) recognizes 5 main indications for arthroscopy:

1. Internal derangement of the TMJ, mainly Wilkes stages II, III, and IV

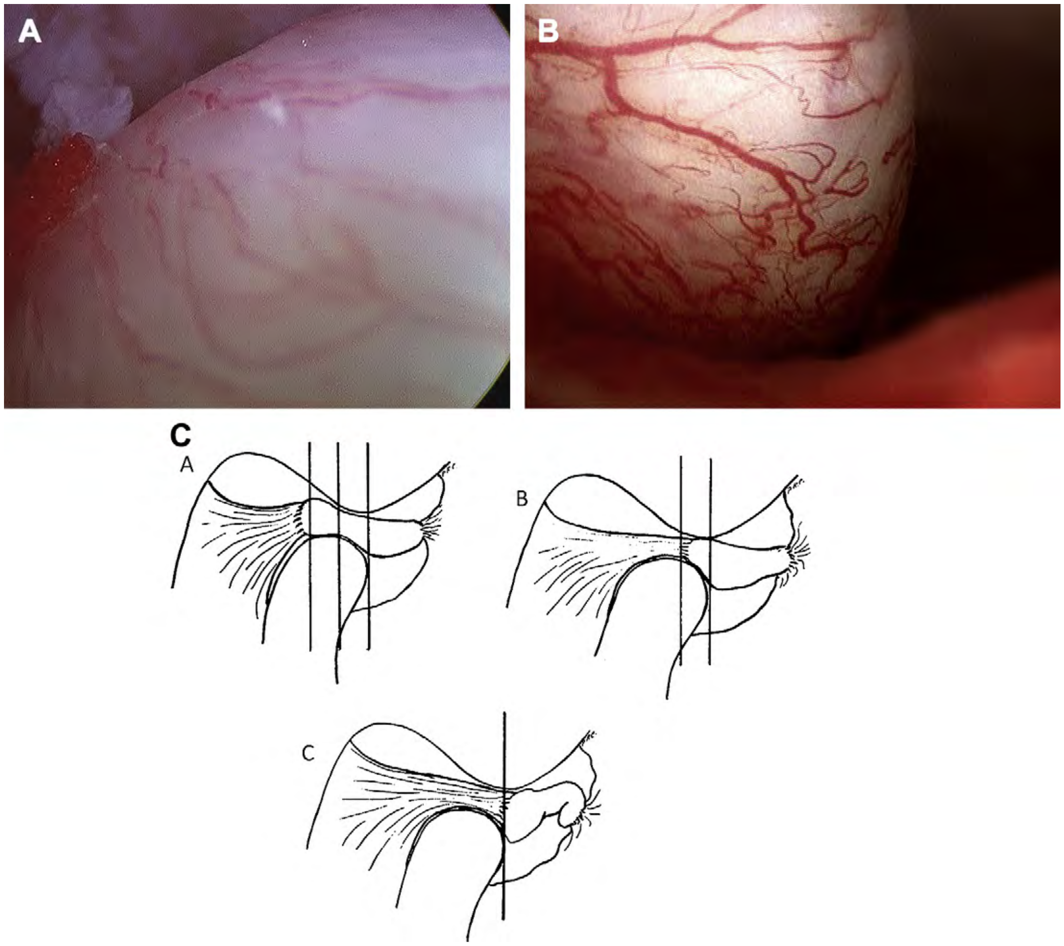

Fig. 6. Articular disc. (*A*, *B*) Arthroscopic views of the articular disc. (*C*) The roofing concept: A, 100%; B, 50%; C, 0%.

2. Degenerative joint disease
3. Synovitis
4. Painful hypermobility or recidivist mandibular luxation of discal cause
5. Hypomobility caused by intra-articular adherences.

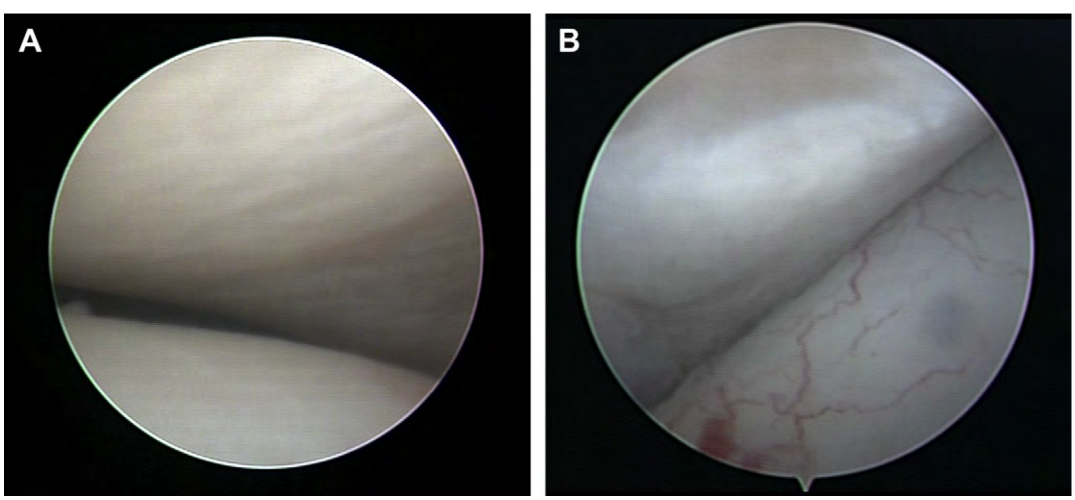

Fig. 7. Intermediate zone. (*A*, *B*) Arthroscopic views of the intermediate zone: (*A*) healthy-appearing area, (*B*) focal areas of hyperemia.

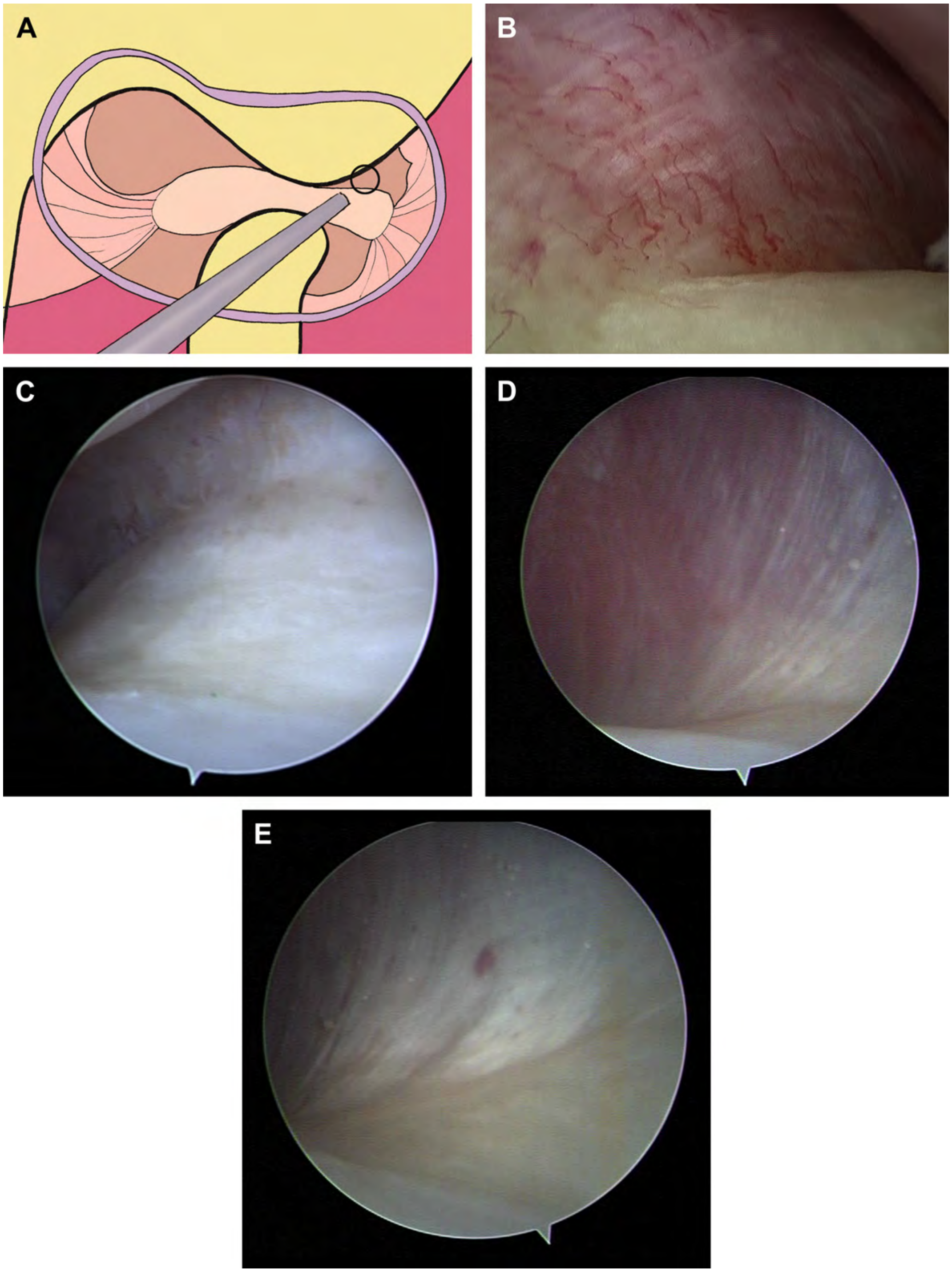

Fig. 8. Anterior recess. (*A*) Scheme. (*B–E*) Arthroscopic views of the anterior recess: (*B*) hyperemic appearance, (*C–E*) healthy-appearing area.

Some investigators have proposed additional indications:

a. Inflammatory arthropathies (systemic arthritis)
b. Articular symptoms subsidiary to orthognathic surgery
c. Revision of the TMJ in cases of intra-articular implants.

The main contraindications for TMJ arthroscopic procedures are:

1. Cutaneous, otic, or articular infection
2. Tumor with risk of extension

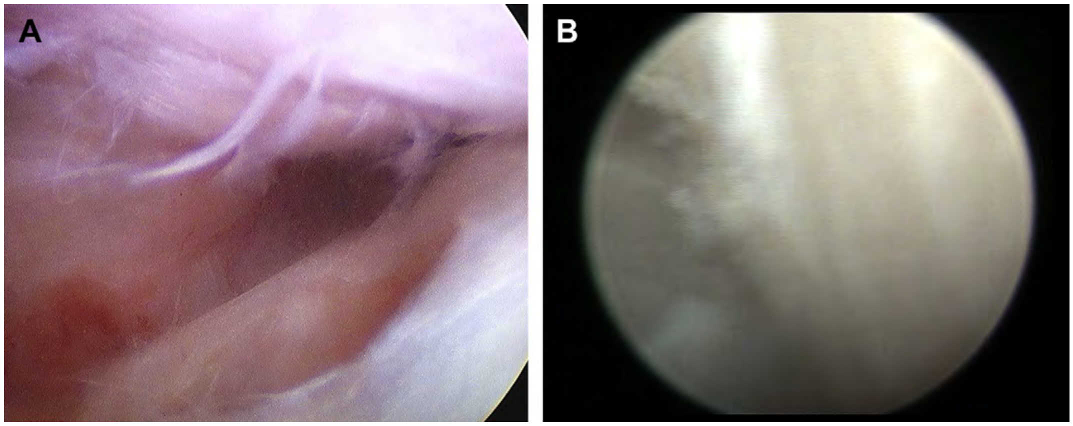

Fig. 9. (*A*) Arthroscopic view of a disc perforation from the superior joint space. (*B*) Arthroscopic view of the condyle from the inferior joint space.

3. Psychiatric disorders
4. Patients in whom the TMJ joint is difficult to palpate (obesity, multioperated)
5. Severe fibrous or osseous ankylosis.

Surgical Technique

Magnetic resonance imaging (MRI) is always advisable before any arthroscopic surgery to properly visualize the relationship of the articular disc and soft tissue with the bony components of the TMJ. It must be performed with the condyle seated and forward (Fig. 10). ALL can be performed by a single-puncture or a double-puncture technique. If a single-puncture technique is used, lysis is directly performed with the arthroscope. When a double-puncture technique is used, the second cannula is used for the introduction of the instruments that break the adherences, such as hooked probes or biopsy forceps, under direct vision. The technique can be complemented with the injection of substances such as corticoids, ideally subsynovially in cases of severe synovitis under direct vision.

As described by McCain and colleagues, the first puncture is placed at the maximum concavity of the glenoid fossa. The pure single-puncture technique can be used in diagnostic cases or simply lavaging with the use of an outflow needle. With a controlled rotational movement, the sharp trocar penetrates the skin at the fossa puncture site (Fig. 11). Following scraping of the zygomatic bone until it steps off the ledge, the trocar must be rotated until it penetrates the joint capsule at a depth of between 10 and 15 mm (Fig. 12). At this point, the sharp trocar is removed and a blunt trocar is introduced. Further introduction of the cannula is performed into the joint space, which may be inserted 20 to 25 mm from the skin (Fig. 13). Later, the arthroscope can be introduced through the cannula (Fig. 14A). The image on the monitor should confirm adequate entry into the joint space. After an

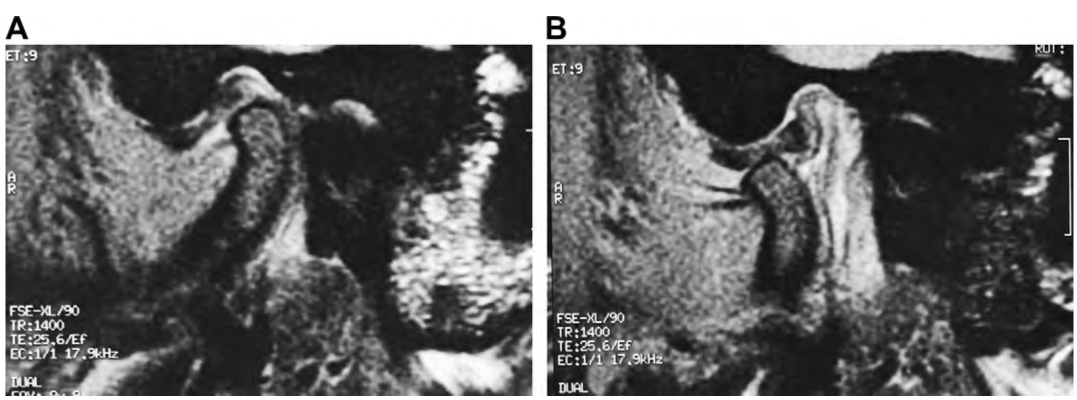

Fig. 10. MRI of the TMJ. (*A*) The condyle is seated. (*B*) The condyle is forward.

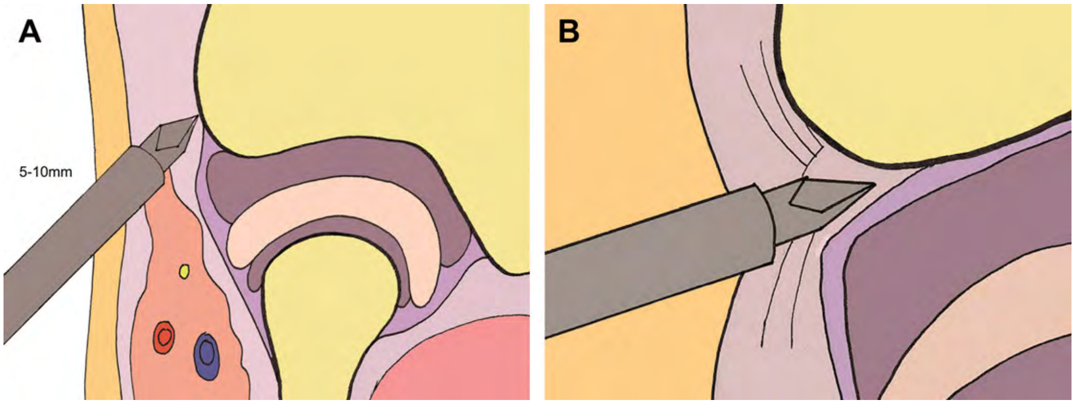

Fig. 11. (*A*, *B*) The sharp trocar penetrating the skin at the fossa puncture site.

insufflation of the capsule with 2 to 3 mL, a 22-gauge needle is introduced 5 mm anterior and 5 mm posterior to the fossa puncture site (see Fig. 14B) until a continuous irrigation with Ringer solution is obtained (see Fig. 14C).

Usually, when the diagnostic sweep is complete, the second cannula can be introduced (Fig. 15). It is recommended that the arthroscope illuminate the most anterolateral aspect of the anterior recess before introducing the second, or working, cannula at this point. The working cannula must be vectored into the anterior recess following the principles of triangulation, which serve to blindly bring 2 objects together in space (Fig. 16).

Results of ALL

In analyzing the literature concerning ALL, 2 main concerns exist: only a few randomized studies comparing ALL with other treatments for internal derangement of the TMJ are present; and different arthroscopic techniques are used for the treatment of the same entity, and they are not randomly assessed.

Sanders and Buoncristiani described their clinical experience with the use of ALL, showing excellent results in 82% of their patients with a maximal interincisal opening (MIO) equal to or greater than 40 mm with little or no pain in the TMJ. Indresano showed a 73% success rate in a series of 64 patients undergoing arthroscopy. Moses and colleagues recommended anterior-posterior movements with the cannula and blunt trocar, showing pain reduction in 92% of 237 patients undergoing ALL, and improvement of mouth opening with an MIO greater than 40 mm in 78%. Perrot and colleagues observed a decrease of pain and an increase of joint mobility in a prospective study in 76 joints treated by ALL and injection of corticoids. Clark and colleagues reported pain reduction in 57% of patients and 83% return of mobility, with an range of motion increasing from 30

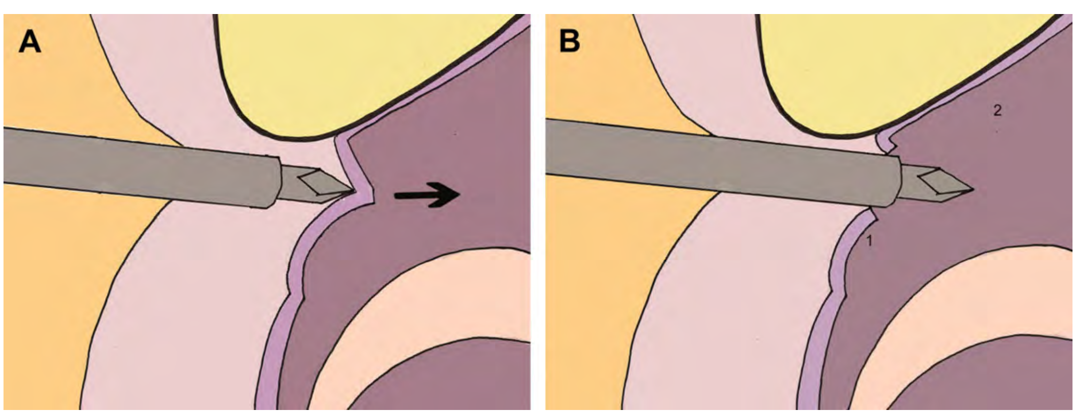

Fig. 12. (*A*, *B*) The sharp trocar penetrating the joint capsule. 1, capsule; 2, upper joint space.

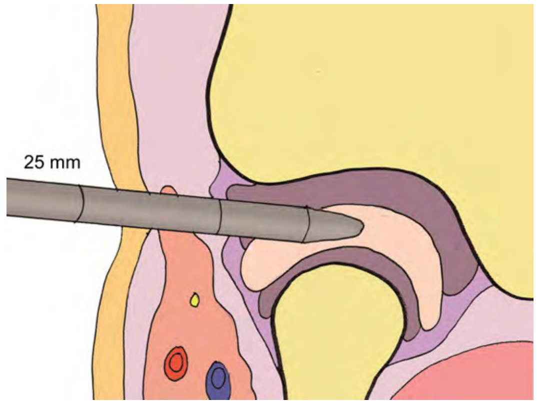

Fig. 13. The introduction of the cannula into the joint space.

to 43 mm. They concluded that the influence of the position of the disc was slight, because lysis and lavage modified the position of the disc. In a follow-up study of 63 patients during 4 years, Moore concluded that ALL was beneficial in 87% of the patients. Kurita and colleagues reported an overall 86% success rate when using ALL for the treatment of internal derangement of the TMJ. Dimitroulis reported a good outcome in 66% of their patients undergoing ALL, a mild improvement in 18%, and no improvement in 16%. González-García and colleagues showed that ALL was as effective as operative arthroscopy in terms of reducing postoperative pain or increasing mouth opening at any stage of the follow-up period. Kondoh and colleagues reported 80% success rate when using ALL for internal derangement of the TMJ. Sorel and Piecuch supported the long-term beneficial effect of ALL for the treatment of chronic pain in the TMJ. Ninety-one percent of the patients followed up for 4.4 years had no further significant complaints, with a significant increase in mouth opening.

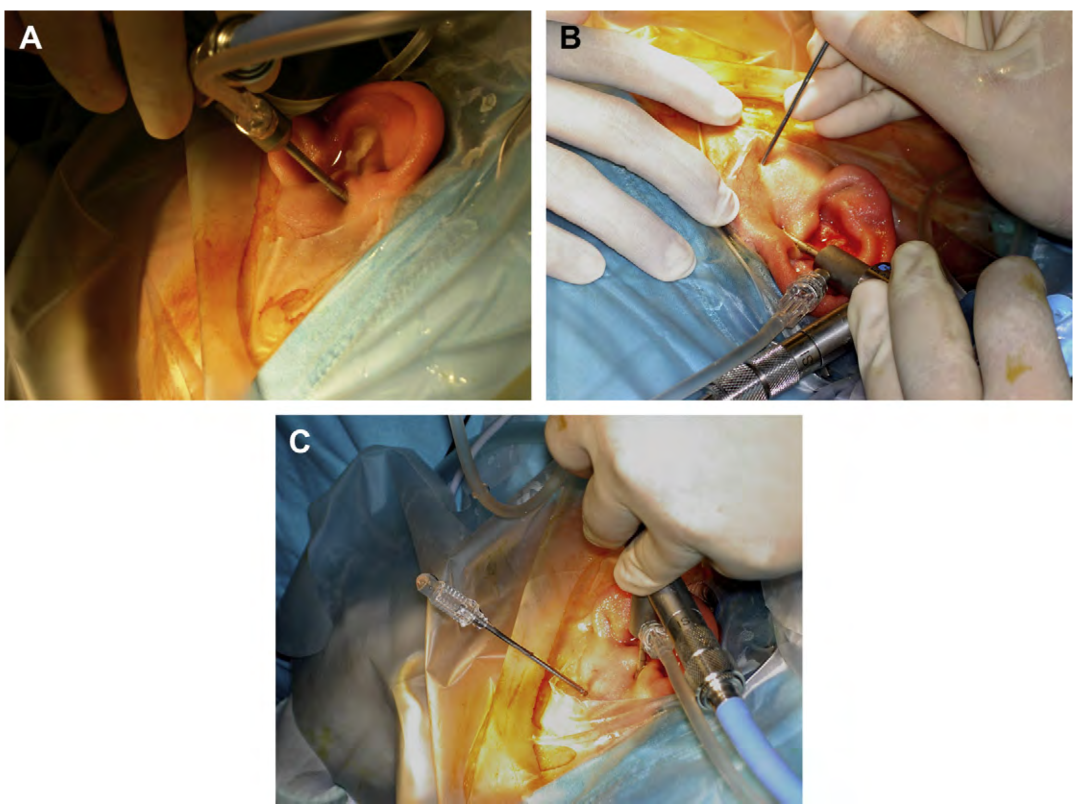

Fig. 14. Clinical view of the introduction of the arthroscope in the single-puncture technique. (*A*) Introduction of the arthroscope. (*B*) Insertion of a 22-gauge needle. (*C*) Continuous irrigation with Ringer solution.

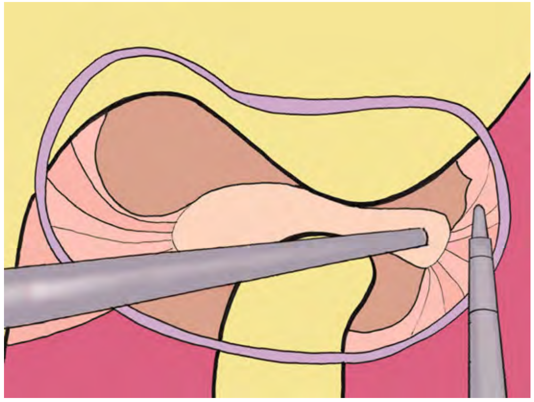

Fig. 15. Introduction of the second, or working, cannula.

The role of postoperative physiotherapy following arthroscopy is controversial. Some investigators have argued that favorable results obtained by arthroscopy may be attributable to physiotherapy. However, in a randomized controlled study of patients undergoing physiotherapy with or without ALL, Stetenga and colleagues encountered statistically significant better results for the group of patients undergoing ALL. Several papers have shown promising results for arthrocentesis, especially when used in cases of acute disc displacement without disc reduction. When compared with ALL, the latter generally has had a slightly superior overall success rate.

Regarding the success rate according to the stage of internal derangement, variable results have been previously reported in the literature. Bronstein and Merrill observed a success rate of 96% for stage II, 83% for stage III, 88% for stage IV, and 63% for stage V. These investigators used ALL and also advance or operative arthroscopy (OA). Holmlund and colleagues reported a success rate of only 50% for patients suffering chronic closed lock (CCL) with osteoarthrosis, corresponding to Wilkes stage V, whereas Murakami and colleagues reported a success rate of approximately 90% for ALL in stages III and IV, and needed OA for a success rate of 93% in stage V. Recently, in a study of 26 joints that underwent ALL, Smolka and Iizuka found an overall acceptable success rate of 78.3%, although the treatment was less successful for stages IV and V (71.4% and 75%, respectively) than for stages II and III (80% and 85.7%, respectively).

Several arthroscopic findings concerning internal derangement with CCL of the TMJ have been reported in the literature. Fibrillation seems to be the most common arthroscopic finding (76%). Synovitis and hyperemia have been reported to occur in 41% to 93% of the patients undergoing arthroscopy for internal derangement of the TMJ. The status of the articular surface or the synovial lining may not necessarily improve following ALL, even though a clear improvement in pain and mandibular function was noted., In a series of 30 patients who underwent 2 consecutive ALL, Hamada and colleagues concluded that a clinically verified improvement in patients with internal derangement of the TMJ was not necessarily accompanied by healing of the diseased tissues.

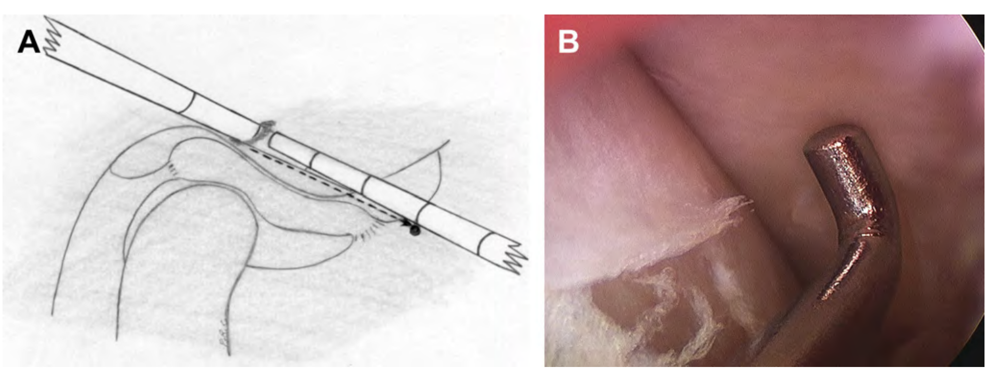

Fig. 16. The triangulation technique. (*A*) The introduction of the second cannula. (*B*) Introduction of a blunt probe through the second, or working, cannula.

According to the study by Moses and Topper of the position of the disc following ALL assessed by MRI, the effect of lysis and lavage is not related to the reposition of the disc in the long-term follow-up, but to the mobilization of the disc and the removal of degenerative products that produce inflammation.

OA includes release of the joint capsule or the pterygoid muscle to allow for posterior repositioning of the disc, as well as electrocautery of the posterior ligament. Preliminary good results with OA were obtained by McCain, Davis and colleagues, and Tarro, although direct comparison studies between OA and ALL were still absent. In a posterior study by Indresano, 103 of 188 patients who underwent ALL, and 121 of 212 patients who underwent OA, were evaluated and compared in relation to pain and function. Within the group of patients with ALL, followed for 8.3 years, pain was reduced by 71%, and disability was reduced by 66%. In comparison, patients undergoing OA, with a mean follow-up of 4.8 years, showed a pain reduction of 81% and a disability improvement of 86%. In this study, differences were statistically significant. Within the ALL group, 37% of the patients had further surgery and therefore had failed the first procedure, in contrast with only 9% of the patients in the OA group. In contrast, in a comparison study of 41 joints treated with ALL and 73 joints treated with OA in patients with advanced internal derangement (Wilkes III to V), Miyamoto and colleagues found similar good results in pain and function for both treatment modalities, and concluded that ALL within the superior joint space was suitable and effective for patients suffering advanced internal derangement with locking, and that OA was necessary only if early wide mouth opening was required.

Summary

Acute knowledge of the arthroscopic anatomy of the TMJ with its classic areas and landmarks is necessary to effectively and safely perform ALL of the TMJ. ALL is a useful technique for the treatment of patients with internal derangement of the TMJ with minimal complications. A systematic examination of the superior joint space is always performed, including good visualization of the superoanterior recess. It is necessary to assess disc mobility by pressing the posterior ligament with a blunt obturator, and slight electrocautery can be performed on the synovium. From the literature findings, it can be argued that there is no overall significant difference between ALL and OA in reduction of pain and improvement of mandibular function.

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Atlas of the Oral and Maxillofacial Surgery Clinics

Advanced Arthroscopy of the Temporomandibular Joint

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Patient selection for advanced operative arthroscopy

Indications

Advanced operative arthroscopic procedures are indicated for disabling joint conditions refractory to medical management and primary arthroscopy alone and that require internal structural modifications of the temporomandibular joint (TMJ). Examples include internal derangements, hypomobility secondary to adhesions, synovitis, degenerative joint disease, and hypermobility resulting in painful subluxation or dislocation.

Contraindications

Contraindications include skin infection, possible tumor seeding, and medical and other circumstances unique to patients.

Diagnosis	Procedures
Wilkes II, III, early IV stages	Arthroscopic discopexy
Wilkes late IV stage	Arthroscopic debridement, lysis and lavage
Wilkes V	Arthroscopic debridement
Ankylosing osteoarthrosis	Arthroscopic debridement
Mandibular hypermobility	Scar contracture
Synovitis	Arthroscopic lysis and lavage, synovectomy, instillation of medicaments

Armamentarium for advanced TMJ arthroscopy

Basic Armamentarium

Arthroscope

Arthroscopes are available from several suppliers but share similar features. The arthroscope should be less than 2 mm in diameter with an angle of view of 30°. The focal distance should be 0 to infinity. This specification is an absolutely key point because scopes that have focal lengths greater than 1 mm do not permit adequate visualization during advanced arthroscopy (Fig. 1). Other important factors are resolution or sharpness of the image, distortion and flatness of the field, color response, and brightness. The light source should be capable of providing 5000 K color temperature.

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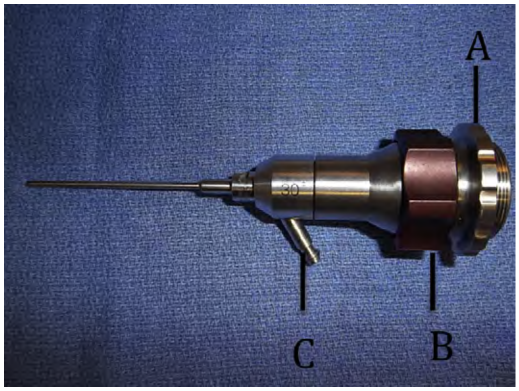

Fig. 1. A 1.9-mm arthroscope with (*A*) C-mount attachment, (*B*) focusing ring, and (*C*) light source attachment.

The arthroscope is a delicate instrument, not to be used in the same manner as a surgical tool. Although the housing is made of materials, such as aluminum and steel, the internal lens components are glass rods, some as small as 1 mm in diameter. A cracked or chipped lens may damage the arthroscope beyond repair. Awareness of the delicacy of the instrument and careful handling is the pathway to long life for your endoscope.

Cannulas

The operative system consists of 2 similar cannulas, a trocar and an obturator (Fig. 2). Devices inserted in the cannula, including the scope, need to have a diameter that is at least 0.1 mm smaller than the inner diameter of the cannula. This diameter permits the appropriate ingress and egress of irrigation fluid maintaining joint distention and clarity. By having similar cannulas, instruments and scopes can easily be switched between portals during the procedure. The cannula delivery system facilitates not only use of hand instruments in the joint but also irrigation and maintenance of joint insufflation. Markings on the cannulas begin at 15 mm from the tip and continue in 5-mm increments, allowing the surgeon to monitor depth of penetration. For larger diameter instruments (ie, 2.7 mm) used in more aggressive debridements, the primary author has designed a switch stick facilitating the interchange between the 2.0- and 3.0-mm diameter cannulas.

Probes

The straight probe is the most basic arthroscopic hand instrument. It is used for palpation, severing adhesions, and mobilization/temporary immobilization of tissue (ie, disc). The hooked probe is similar to the later except for a small terminal hook. It is the preferred instrument for palpation in cases of chondromalacia. The typical use of this probe is to elevate the anterior aspect of the disc after anterior releasing procedures and to complete the dissection of the disc from the capsule and the pterygoid muscle. The hooked probe is also preferred in difficult cases of disc reduction, with lax/redundant retrodiscal tissue, where a straight probe may lacerate the structure. Hooking of the oblique protuberance before disc reduction enables reduction without herniation of tissue (Fig. 3).

Fig. 2. Operative system showing cannulas with scoring marks and sharp trocars.

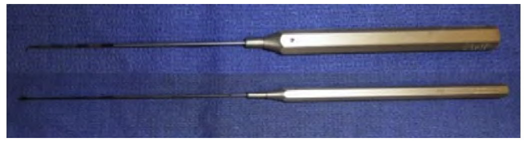

Fig. 3. Hooked and straight probes.

Advanced Armamentarium

Biopsy forceps

The serrated-type forceps have cupped beaks and are used for small biopsy samples and for the debridement of pathologic or fragmented tissues. The basket-type forceps harvest mostly full-thickness biopsy specimens (ie, synovial tissue) (Fig. 4).

French #5 myringotomy suction tip

This instrument will evacuate clots or heme during arthroscopy. The 2.0-mm cannula easily accommodates this suction.

Meniscus Mender

This packaged set consists of straight and curved spinal needles with a stylet and a suture loop used to snare the suture once passed through the needle. While in the process of designing a less invasive replica of Meniscus Mender I and II (Instrument Makar, Okemos, Michigan), the primary author uses, for most situations, a 22-Ga needle to pass the suture for discopexy procedures (Fig. 5).

2.4-mm suction punch

The 2.4-mm suction punch is a valuable and efficient instrument when more advanced debridements or partial discectomies are required. It is placed down a 3-mm cannula, and works by cupping and biting the tissue at the distal end. Suction is then applied at the proximal end to withdraw the tissue from the joint and the instrument (see Fig. 4).

Other hand instruments

The authors use the bone rasps to smooth bone and curettes to debride clumps of adhesive fibrocartilage of bone surface (Figs. 6, 7) The golden retriever is a valuable magnetized instrument specialized in retrieval of intraarticular broken instruments (Fig. 8).

Motorized Instruments

The unique concept of motorized shavers and abraders enables suctioning of the arthroscopic field while cutting and removing tissue in an efficient manner. Four factors are paramount for these instruments to function efficiently: (1) the design of the cutting blade, (2) the pressure balance between the suction and the continuous irrigation fluid, (3) the revolution speed (revolutions per

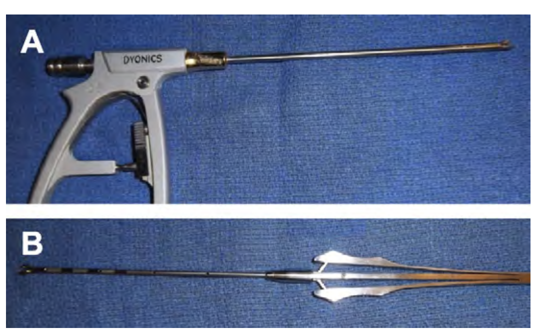

Fig. 4. (*A*) Cupped biopsy forceps, (*B*) 2.4 suction bunch forceps.

Fig. 5. The Meniscus Mender II has a lasso (*top*), an obturator (*center*), and a small-diameter cannula needle (*bottom*). (*From* McCain JP. Principles and practice of temporomandibular joint arthroscopy. St Louis (MO): Mosby; 1996; with permission.)

Fig. 6. Leibinger bone rasps, concave (*left*) and convex (*right*). (*From* McCain JP. Principles and practice of temporomandibular joint arthroscopy. St Louis (MO): Mosby; 1996; with permission.)

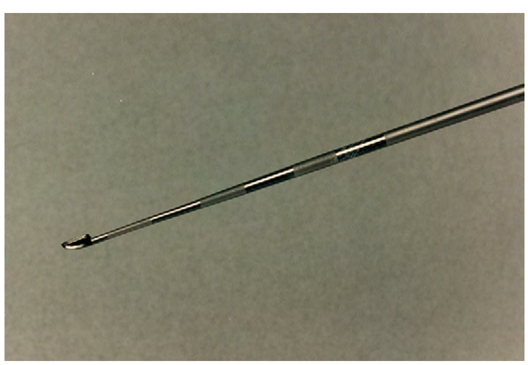

Fig. 7. Close-up view of Leibinger curette. (*From* McCain JP. Principles and practice of temporomandibular joint arthroscopy. St Louis (MO): Mosby; 1996; with permission.)

Fig. 8. A 1.7-mm magnetized golden retriever. It can retrieve broken instruments via the 3.0-mm cannula. (*From* McCain JP. Principles and practice of temporomandibular joint arthroscopy. St Louis (MO): Mosby; 1996; with permission.)

minute) of the instrument, and (4) the type of tissue that the surgeon is attempting to cut. The primary author has discovered that the ultimate parameters of efficiency for the shaver are reached at the lower spectrum revolutions per minute–range speed. After developing a refined intraarticular tactile sense for the instrument, the author has noticed that the most efficient shaving occurs with a repeated paw-and-dab motion.

Shavers

The larger of the 2 shavers widely in use, 2.9 mm in diameter, is used for more aggressive arthroscopic arthroplasty. A 2.4-mm diameter suction punch may become necessary with the use of this shaver. For the sake of keeping procedures as minimally invasive as possible, this author has lately only used a 1.9-mm shaver.

Whisker shaver

The one advantage of this shaver is its ability to prevent intraarticular iatrogenic complications. The instrument has been so profiled that the articular surfaces are completely protected from the cutting portion of the active part. The perforations in the external sleeve of the instrument promote a suction effect on the soft tissue that the inner blade cuts next. The whisker shaver has been designed for the debridement of fine fragmented fibrocartilage from articular surfaces, small fibrous adhesions, or small fragments of the disc periphery. It may remove fibrotic or desiccated synovial tissue; however, its use on intact/vascular synovium is discouraged (Fig. 9).

Full radius shaver

Available in 1.9 and 2.9 mm diameter, it is a more aggressive and efficient instrument designed to resect tissue of an even more fibrotic consistency, such as fibrous bands, adhesions, large areas of desiccated synovium, fragmented edges of meniscus, and advanced chondromalacia (see Fig. 9).

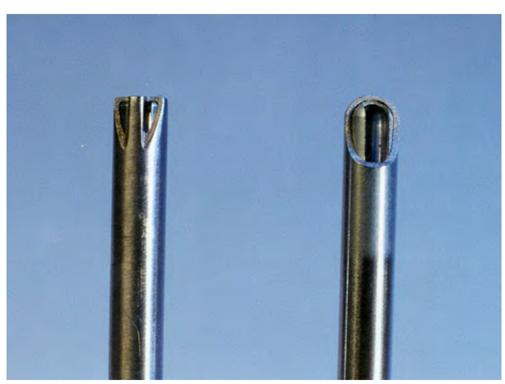

Fig. 9. Close-up of Dyonics whisker shaver (Smith and Nephew, UK) (*left*) and full radius shaver (*right*). (*From* McCain JP. Principles and practice of temporomandibular joint arthroscopy. St Louis: Mosby; 1996; with permission.)

Abraders

These bone drills (the round and barrel-shaped abraders) only come in 2.9 mm and are used to decorticate the osseous structures and create pinpoint areas of microhemorrhage to promote cartilaginous regeneration (Fig. 10).

Electrosurgery

Electrosurgery is the use of high-frequency electric currents to facilitate a tissue change. The human body's electrolyte composition makes it a conductor of electricity. During electrocautery, an alternating current is passed to the surgical electrode probe in the form of heat. The manner in which the tissue responds to the electrothermal energy depends on the waveform of the current, the power at the electrode tip, the time of exposure at the electric tip, and the cooling of the tissue with blood circulation. The continuous sinusoidal waveform is used for the cutting mode because it mechanically disrupts cells. The attenuated or dampened waveform, which eventually oscillates down to resting potential, is used for the coagulating mode.

The McCain monopolar and bipolar electrocautery probes (Leibinger, Irving, TX, USA) are fully insulated except at the tips of the instruments. The bipolar probes are by far the most commonly used electrocautery probes. The safer, more rigid probes have the ability to manipulate tissue while delivering the electrical energy. In order not to compromise the insulation of the probes, the recommended settings of the generator should not be exceeded. Although common settings exist for each tip, the individual settings may change based on clinical experience. The introduction and removal of the electrocautery probe in the working cannula is a very deliberate motion. Abrasion of insulation in the process should be avoided at all costs because it can expose another potentially active area away from the tip of the instrument. If this happens, an area of the joint can be iatrogenically injured while outside the arthroscopic field of view. No grounding pad is necessary for bipolar electrocautery, and the irrigation fluid may contain electrolytes. The thousands of arthroscopic procedures performed by this author, including posterior synovial pouch cauterization, electrosurgical anterior release, electrosurgical synovectomy, and electrocautery for hemostasis, have awarded the experience necessary to understand the effects of electrocautery on intraarticular temperature (Fig. 11). The best initial setting for contracture procedures is 15 W and 30 W for coagulation.

Monopolar electrocautery is used infrequently. A grounding pad is necessary, and the irrigation fluid must be sterile water, a non–electrolyte-containing solution. The monopolar electrocautery may be used to perform the same procedures more commonly accomplished by bipolar electrocautery.

Laser

Light amplification by stimulated emission of radiation or laser technology transmits energy in the form of a light beam. The laser light beam is collimated and formed of equally spaced and coherent wavelengths. Laser energy is delivered as either a continuous or a pulsated beam of light. The

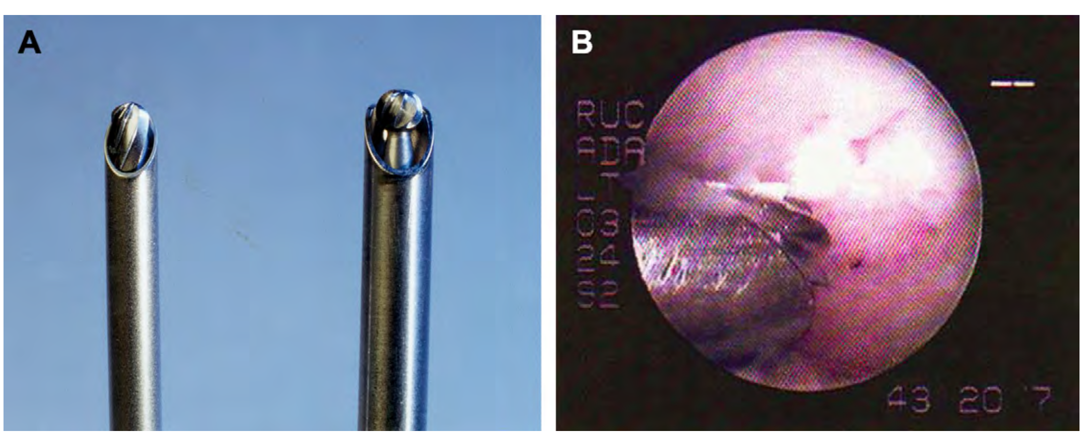

Fig. 10. (*A*) Close-up of barrel abrader (*left*) and round abrader (*right*). (*B*) Barrel abrader in joint contouring articular surface. (*From* McCain JP. Principles and practice of temporomandibular joint arthroscopy. St Louis (MO): Mosby; 1996; with permission.)

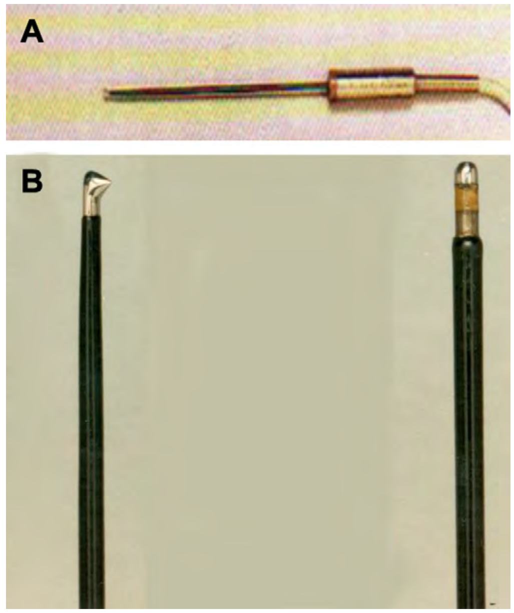

Fig. 11. (*A*) McCain electrocautery probes. (*B*) Close-up of McCain electrocautery tips. Shown are monopolar sharp hook (*left*) and bipolar blunt (*right*). (*From* McCain JP. Principles and practice of temporomandibular joint arthroscopy. St Louis (MO): Mosby; 1996; with permission.)

wavelength of a particular laser determines the physical properties of a laser in the clinical use setting.

Holmium YAG laser

This laser's wavelength is 2140 nm, making it somewhat similar to the CO_2 laser with regard to its high hydro absorbability. The holmium laser, however, has a limited depth of penetration (0.3–0.5 mm), making it very useful intraarticularly. In this author's hands, this laser variety is the most versatile for arthroscopic techniques on the TMJ, such as anterior release (cutting), synovectomy, posterior scarification, and debridement of fibrocartilage. The small size of the delivery tip facilitates excellent access in limited spaces, whereas its metal encasement prevents the breakage of this quartz fiber. To this date, the holmium YAG laser is considered the most safe and effective modality for intraarticular TMJ delivery of energy. A 0.5-mm holmium laser fiber is secured within a metal hand piece. The diameter of this device is 1.8 mm. The device fits down the 2.0-mm working cannula.

Laser settings for cutting	10 Hz/Reputations	9 W	0.09 J
Laser settings for ablation	8 Hz/Reputations	4 W	0.5 J
Laser settings for contracture	5 Hz/Reputations	2 W	0.40 J

The laser radiation is well absorbed by most biologic tissues, which allows for precise tissue removal. These desirable characteristics suggest a potentially useful arthroscopic tool. In using this laser on patients, both authors have been impressed with the ease and rapidity with which adhesions and fibrillations can be ablated, cartilage sculptured, and rapid coagulation obtained in areas of hemorrhage. In addition, triangulation and manipulation by placing the fiber directly through the skin has not only reduced operating time but has also facilitated more complete removal of adhesions from all areas of the joint compartment, thus, releasing the disc for better function (Fig. 12). Other laser types have not been found to be beneficial in TMJ.

Radiofrequency Coblation Microdebridement (ArthroCare, USA)

The newest modality for advanced arthroscopy is the radiofrequency (RF) coblation instrumentation. Coblation uses a controlled, non–heat-driven process in which bipolar radiofrequency energy

Fig. 12. Introduction of the holmium laser fiber (*blue*) to the joint via cannula.

excites the electrodes in a conductive medium, usually saline solution, to create a precisely focused, charged plasma gas. The energized particles in the plasma field have sufficient energy to break the molecular bonds within the tissue, causing the tissue to dissolve or contract at low temperatures (typically 40°C–70°C). Because the RF current does not pass directly through the tissue during the coblation process, tissue heating is minimal. The result is volumetric removal of the target tissue with minimal damage to the surrounding healthy tissue. Coblation technology permits cutting, coagulation, ablation, and contracture (Fig. 13).

RF cutting setting	≥No. 5 (≥200 V)
RF coagulation setting	No. 2 (125 V) or default setting for coagulation
RF ablation setting	≥No. 5 (≥200 V)
RF contracture setting	No. 2 (125 V)

An important technical note for using bipolar or monopolar electrocautery and RF coblation is to monitor the temperature of irrigating fluid as it exits from the cannula so as not to cause thermal damage to surrounding tissue. Also, delivering irrigation in a pulsed, intermittent manner minimizes the risk of overheating the joint.

Procedures of advanced arthroscopy of the temporomandibular joint

Techniques of Operative Arthroscopy

A variety of techniques are used in the advanced arthroscopic management of patients with internal derangements or degenerative joint disease and may involve ablation and debridement of adhesions, restoration of disc mobility and position, and partial discectomy. Additionally, capsular and discal attachment scarification or plication may be used to help in the reduction of condylar hypermobility.

Fig. 13. Coablation (ArthroCare) probe.

Double-Puncture Technique

After a single-port diagnostic sweep is complete, the puncture for a second cannula can be performed. For this portal to be most effective in diagnostic and operative arthroscopy, the arthroscope should illuminate the most anterolateral aspect of the anterior recess. Then, swiveling the arthroscope along the intermediate zone and advancing into the anterior recess, identifying the disc-synovial crease, the scope is swiveled to the most lateral and anterior aspect of the disc-synovial crease. The second puncture needs to be placed exactly in the most anterior and lateral corner of the superior joint space to ensure maximum flexibility of the operative cannula. The variations in second puncture site and technique are dictated by the anterior recess volume and condition of the joint. Conditions, such as synovitis, disc displacement with or without reduction, and osteoarthritis, will present with a normal or reasonable (increased or slightly decreased) anterior pouch volume. The second puncture is performed with the condyle seated in the fossa. The irrigation needle is removed and then the puncture site is located according to triangulation principles. The vectors of instrument orientation create an equilateral triangle, facilitating a repeatable and safe pattern of placement for the second punctures. The depth of the arthroscope can be assessed on the cannula. A second measuring cannula is positioned flat against the tegument with the tip (0-mm marking) contiguous with the scope at the point of entry (skin) and continuous (in a straight line) with the plane of the arthroscope (Figs. 14, 15). The depth of the scope penetration is now translated to the cannula. Depending on the angle formed by the arthroscope and the tegument, 1 to 3 mm can be added to the previous measurement. The site for the second puncture has now been established. The ideal position of the working cannula is directly parallel to the disc-synovial crease in the anterior recess, to facilitate the operative procedures. In a similar fashion to the fossa puncture, the assistant insufflates the joint with 2 mL of irrigation fluid. The trocar/cannula penetrates perpendicular to the tegument then continues in the same direction, ensuring the appropriate geometry and orientation of triangulation previously described. The tendency to direct the cannula posteriorly must be avoided. The trocar is rotated through the skin and advanced until encountering bone at the junction between the anterior aspect of the anterior slope of the articular eminence and the continuation of the zygomatic arch. As opposed to the fossa puncture, no vigorous dissection of the periosteum is performed at this level. The frontal ramus of the temporofacial division of the seventh cranial nerve crosses the anterior aspect of the eminence in close proximity to the second puncture site. Only the tip of the trocar should touch the subjacent cortical plate. Next, the trocar/cannula is rotated through the capsule and synovium. The trocar is observed on the monitor entering the joint space (Fig. 16). Once intraarticular, the trocar is removed and drainage of the irrigating fluid is noted through the cannula. The assistant stabilizes the working cannula while the surgeon proceeds with instrumentation.

In the case of fibrosis or advanced arthrosis, the anterior recess is very difficult to negotiate. The scope is maneuvered as far as possible during the diagnostic sweep. When the arthroscope cannot be advanced or positioned laterally any farther and the condyle has been seated, the second puncture is placed at the most anterolateral aspect permitted by the pathology of that particular joint. The joints

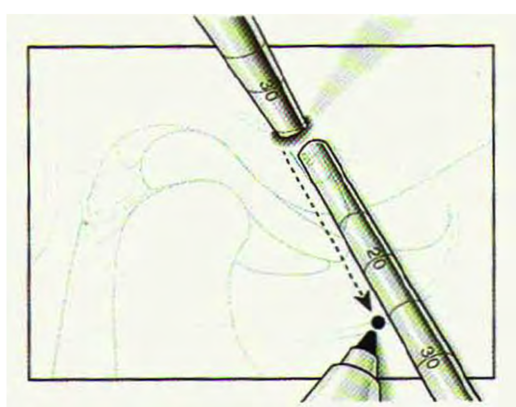

Fig. 14. Vector measuring system. (*From* McCain JP. Principles and practice of temporomandibular joint arthroscopy. St Louis (MO): Mosby; 1996; with permission.)

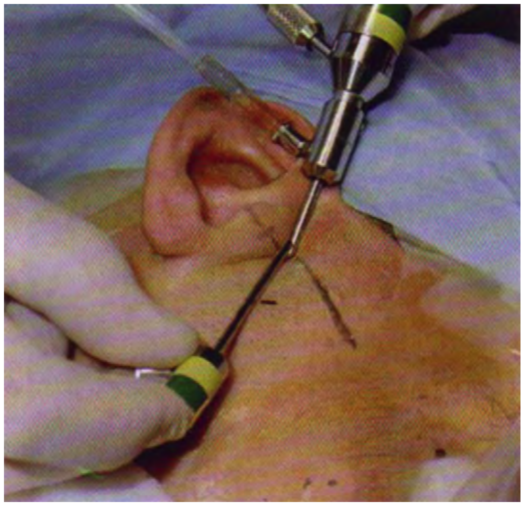

Fig. 15. Vector measuring system. External view. The scope is maintained in this position and the suture needle puncture point is identified using the vector technique. The 20-gauge needle is inserted at the vectored puncture point as shown and penetrates approximately 0.5 in to contact the lateral pole of the condyle. (*From* McCain JP. Principles and practice of temporomandibular joint arthroscopy. St Louis (MO): Mosby; 1996; with permission.)

with advanced arthrofibrosis, stenosis, or fibrous ankylosis present a distorted intraarticular anatomy. Henceforth, the second puncture is placed in the most open area of the joint. When no open space can be visualized arthroscopically, confirmation of the arthroscopic cannula in the superior joint space is confirmed by palpation. Once the cannula position is confirmed, the scope is removed and the obturator inserted. With the blunt obturator, a blind lysis maneuver is performed until osseous contact is perceived. This maneuver will create the opening necessary for the placement of the second puncture.

Arthroscopic Discopexy

This procedure was developed with the thought that restoration of functional intraarticular anatomy, especially in arthroscopic fashion, is the best treatment alternative for managing articular dysfunction. The primary author thinks that symptomatic internal derangements that are refractory to primary arthroscopic lysis and lavage must be restored to a normal condyle-disc relationship, arresting the natural course of osteoarthritis. With this in mind, the discopexy is performed to achieve and maintain this end point. This technique addresses both the reducing and nonreducing disc.

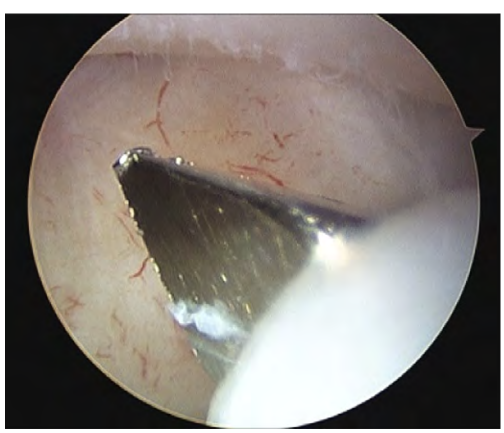

Fig. 16. Target area showing trocar in anterolateral corner in superior space of right TMJ.

Discopexy arthroscopic technique

Anterior release. Once the double puncture has been successfully completed, the disc synovial crease is visually identified. A hook probe was inserted through the operative cannula to confirm the disc synovial crease. Compressing the hook probe along the disc yields a feel of thicker tissue. You can slip off the edge of the disc as you move forward with the hook probe and penetrate the synovium and underlying muscle. This procedure confirms the junction between the articular disc and the synovial capsule. The target for the anterior release is the disc synovial crease. The intraarticular incision begins at the juncture between the pterygoid shadow and the anterior recessed synovium in the disc synovial crease (Fig. 17).

The incision is made with electrocautery or ArthroCare through the synovial membrane extending laterally to the vascular hump. The vascular hump is usually in the center portion of the anterior recess. The incision penetrates the synovial membrane, slicing the capsule, and the pterygoid muscle is identified. The superior belly of the pterygoid muscle inserts into the articular disc. A pterygoid myotomy is completed from the extreme medial component of the release to the vascular hump laterally. All muscle fibers are resected from the disc under direct arthroscopic visualization. The cut through the superior belly of the pterygoid muscle is complete when a space between the superior belly of the pterygoid muscle and inferior belly of the pterygoid muscle is encountered and the inferior belly of the pterygoid muscle can be seen to be more purple in color than the superior belly. The cut is made in the superior belly of the pterygoid muscle but at the tendinous attachment toward the disc to avoid bleeding. Small bleeding points can be controlled with a laser. On occasion it is necessary to cauterize the bleeding points with bipolar cautery. Care must be taken to avoid cutting to the vascular hump or significant bleeding will be encountered. Severe bleeding dictates the need to place an intraarticular tamponading balloon. Lateral to the vascular hump, one may also traumatize the masseteric nerve with a resultant masseteric atrophy postoperatively on patients. Once the release is completed, disc reduction is the next step.

Disc reduction. When the condyle is in a closed position, the operative cannula and the scope are in the anterior recess, and the anterior release has been completed, the operative cannula and the scope are then walked back in the lateral sulcus to the posterior pouch. Once these two instruments reach the peak of the articular eminence, the condyle is pulled forward and then both instruments can drop into the posterior pouch. The disc is reduced by compressing the retrodiscal tissue laterally with a straight probe while the condyle is in a forward or forward and contralateral position, or occasionally it is necessary to reduce the disc by taking a hook probe and compressing the oblique protuberance. Occasionally the disc will hold its position, most of the time it will slip back forward. If the disc cannot be reduced, it is necessary to go back into the anterior pouch and extend and deepen the anterior release (Fig. 18).

Retrodiscal scarification or contracture. Retrodiscal tissue is contracted using bipolar cautery, laser, or ArthroCare. The target area of the retrodiscal contracture is generally the boggy and redundant

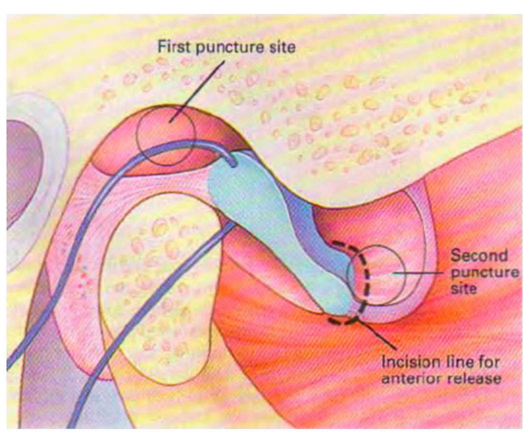

Fig. 17. The ideal position for the second puncture is lateral to the disc synovial juncture (*circle*). The anterior release is performed along the entire medial to lateral breadth of the anterior recess approximately 1 to 2 mm anterior to the anterior band of the disc (*dotted line*). (*From* McCain JP. Principles and practice of temporomandibular joint arthroscopy. St Louis (MO): Mosby; 1996; with permission.)

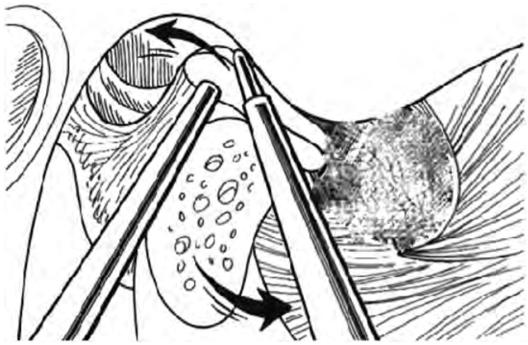

Fig. 18. In the nonreducing disc surgical scenario, the next step is to do a disc reduction maneuver. Note that the fully inflated balloon does not impair the disc reduction maneuver if adequate anterior release has been performed. (*From* McCain JP. Principles and practice of temporomandibular joint arthroscopy. St Louis (MO): Mosby; 1996; with permission.)

synovium found lateral to the oblique protuberance. Low voltage laser, bipolar, or ArthroCare is used to weld that tissue, accomplishing synovectomy superficially and then penetrating deeper into the bilaminar zone, causing scar contracture. Contracture is visible during the procedure, but the most significant contracture occurs 2 to 3 weeks postoperatively as the scar thickens. The purpose of the contracture is to enhance the posterior positioning of the disc and hold it there. The posterior synovectomy and the scar contracture are also done to reduce volume of the joint space so the disc can sit more posteriorly.

Disc fixation. A disc fixation can be accomplished in 1 of 2 ways. The first and more traditional way is the suture discopexy. A second way is by rigid fixation with either resorbable or titanium screws. Regardless of the methodology of fixation, the disc is held in reduction during the course of the fixation. The target area of fixation is the posterior lateral corner of the disc-condyle assembly, the area of the lateral pole where the disc attaches to the condyle. Both suture discopexy and rigid discopexy are ideal in the following situation: class I occlusion with a good joint space and an articular disc that dislocates but does not show remodeling. This condition is found in Wilkes II, III, and early IV joint disease. Whether done with suture or rigid discopexy, in late Wilkes IV and V cases, the procedure only meets with success 60% of the time or so. With the Wilkes II, III, and early IV cases, success rates are upwards of 80%.

Suture disc fixation. While the disc is held in reduction, the vector measuring system is used to target the area of passing of the needle. A 20-gauge, 1.25-in needle threaded with a single O-polydioxanone suture (PDS, Ethicon, Summerville, NJ, USA) is inserted through the skin, subcuticular tissues, touching the condylar head, into the inferior joint space, and then angled superiorly to target the superior lateral aspect of the posterior band of the disc. It is important that this 20-guage needle is inserted underneath the reduction cannula. Once that has been completed, a straight Meniscus Mender II is inserted in the preauricular skin crease 5 to 7 mm below the fossa portal into the superior joint space (Fig. 19). The snare of the Meniscus Mender is then inserted

Fig. 19. Suture passage and retrieval (*outside view*).

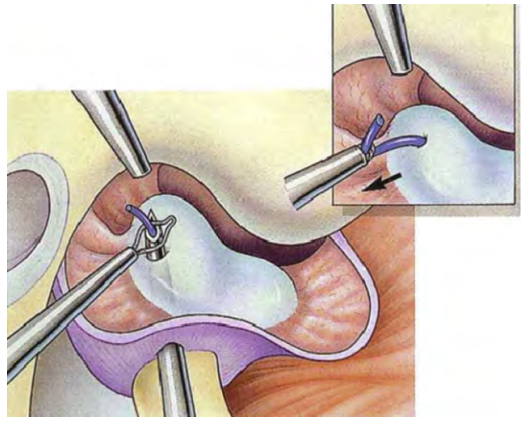

Fig. 20. A 3-dimensional overview of the lassoing procedure. The needle is advanced through the lasso first and then the suture is advanced beyond the needle approximately 1 cm. The suture needle is then withdrawn from the lasso and the lasso is cinched down around the suture material. (*From* McCain JP. Principles and practice of temporomandibular joint arthroscopy. St Louis (MO): Mosby; 1996; with permission.)

through the Meniscus Mender cannula and the suture is passed through the 20-guage needle anterior cut by the snare (Figs 20, 21). Now both of the ends of the suture exit the skin (Fig. 22).

Small skin incisions are made at the exit points of the suture superiorly with a #11 blade. The incisions are 2 to 3 mm through the skin and subcutaneous tissue. Straight hemostat is used to dissect down the suture tracing anteriorly to the capsule. The dissection is along the course of the facial nerve. Posteriorly, the dissection is carried down halfway to the capsule. A #3 half-circle, tapered French spring-eye needle (French eye needle, Anchor, Addison, Illinois) is then used to pass the anterior suture through the slit incision, deep to the capsule, and then back out to the posterior slit incision so that now both free ends of the suture exit posteriorly through the posterior slit incision. While the disc is held in reduction, a tight surgeon's knot is tied plicating the lateral capsule to the subcuticular tissue, reefing the disc and holding the disc in a posterior lateral position (Fig. 23).

Finally, the arthroscope is used to check the position of the disc during closure and opening and the tightness of the suture (Fig. 24). The suture should be tight intraarticularly. It should be snug against the articular disc. Once this has been completed, the instruments are removed and patients examined while still under anesthesia. Make sure that there is no clicking and motion should be fairly tight.

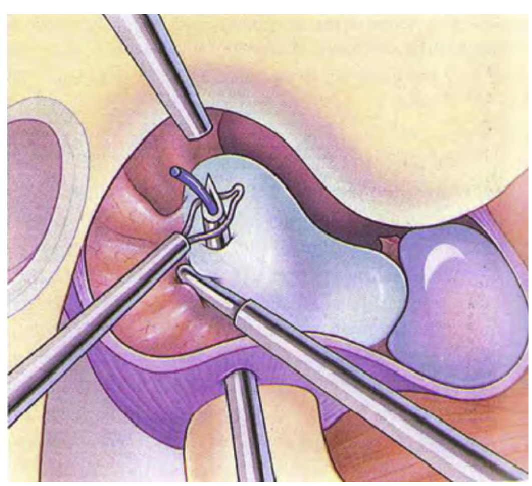

Fig. 21. The disc being held in reduction while the suture is being passed and retrieved. (*From* McCain JP. Principles and practice of temporomandibular joint arthroscopy. St Louis (MO): Mosby; 1996; with permission.)

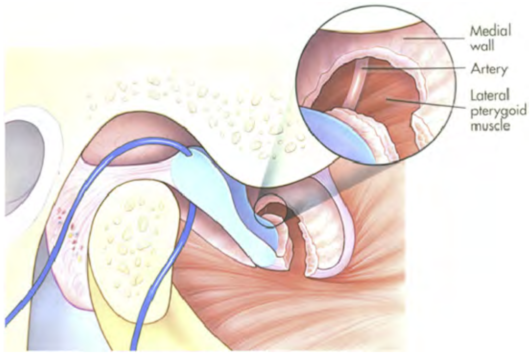

Fig. 22. Demonstrates suture in place and anterior release has been completed through synovium. Note that in the close-up view there is an artery running superiorly and posteriorly across the release. (*From* McCain JP. Principles and practice of temporomandibular joint arthroscopy. St Louis (MO): Mosby; 1996; with permission.)

The other method of treatment is rigid discopexy, which avoids these shortcomings of suture discopexy:

1. It is painful for patients because some of the work is extra-articular.
2. There is a higher risk of temporary facial nerve palsy because of the crossing of the suture near the frontal branch of the facial nerve.
3. Rehabilitation to maximum incisal opening needs to be guarded because the disc is being held simply by 1 stitch so that postoperative physical therapy goes from stage I to stage II: stage I over the first 2 weeks and stage II over weeks 4 through 6.

The goal for patients' opening is 35 mm or to the patients' 2 knuckles, with the index finger and middle finger folded over. Range of motion is attempted to go past borders at the end of 6 weeks. A posterior malocclusion on the operated side develops after suture discopexy but, for the most part, it resolves over a period of time with either flattening of the condyle or reduction of edema.

Rigid disc fixation. Once the anterior release is done and posterior scarification and disc reduction have been completed, the disc is ready for placement of a fixation screw. The disc is maintained in reduction and the condyle is held forward. A third puncture is placed using the vector measuring system (Figs. 25, 26). Ideally speaking, the puncture is approximately 20 mm inferior to the fossa portal. The size of the cannula depends on the size of the screw used: commonly, both authors use a 2.0-mm cannula. The cannula at its distal end has a window so that the screw is visible as it is delivered into the joint and enfacing the disc. Importantly, the angle of placement of this cannula and screw hole should be from posterior to anterior, superior to inferior, and medial to lateral. This placement avoids angling the drill superiorly toward the glenoid fossa and perforating it. Once the disc is

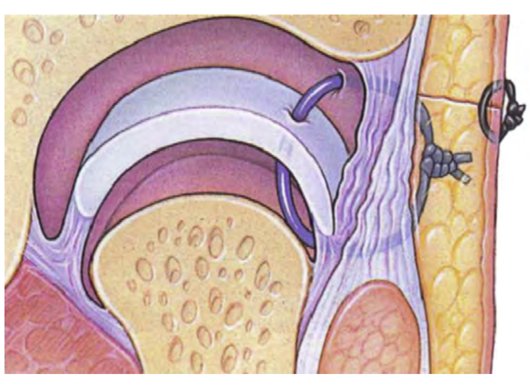

Fig. 23. The knot is buried in the subcutaneous fatty tissue through the nick incision. The skin is then closed primarily with 6-0 nylon interrupted sutures, as shown. (*From* McCain JP. Principles and practice of temporomandibular joint arthroscopy. St Louis (MO): Mosby; 1996; with permission.)

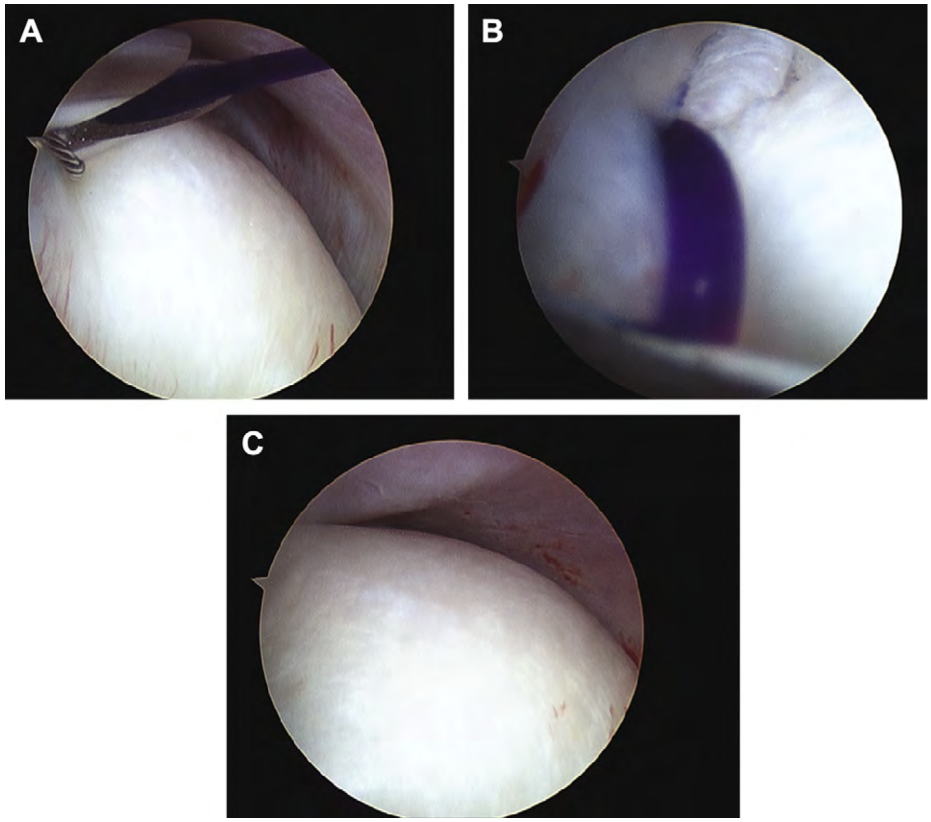

Fig. 24. Endoscopic view of suture discopexy. (*A*) Suture passage and retrieval by meniscus mender. (*B*) Suture knot. (*C*) Reduced disc after suturing.

held in reduction and the cannula has been inserted, the target area is the posterior-lateral corner of the disc-condyle assembly. Holding the cannula still, a drill is delivered through the cannula to the disc and a monocortical screw placed through the condylar head itself (Fig. 27). The drill bit is removed and the screw attached to the screwdriver and delivered to the cannula, then inserted through the disc and into the condyle, screwing it tightly so the disc is now fastened to the condylar head itself. The window on the cannula enables the surgeon to watch the screw actually being turned into position. Once the screw is completely inserted, the cannula is pulled back and the position of the screw is checked arthroscopically to ensure that it engages correctly and its position is correct (Fig. 28). Additionally, one can take a straight probe from the working cannula and wiggle the screw to make sure it is intact. Different types of screws can be applied to the joint. The authors had success with the Osteomed cannulated screw (Osteomed, TX, USA), Inion screw (Inion, Tampere, Finland, USA), and a Smart nail (ConMed Linvatec, FL, USA) (Fig. 29).

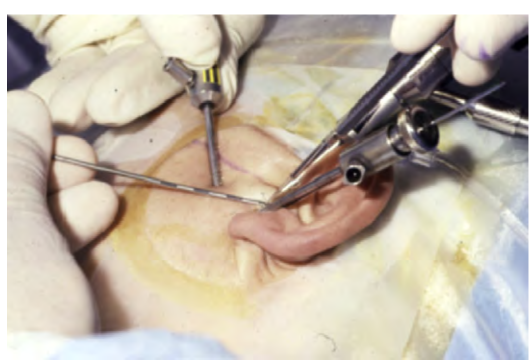

Fig. 25. Vector measuring system in rigid discopexy.

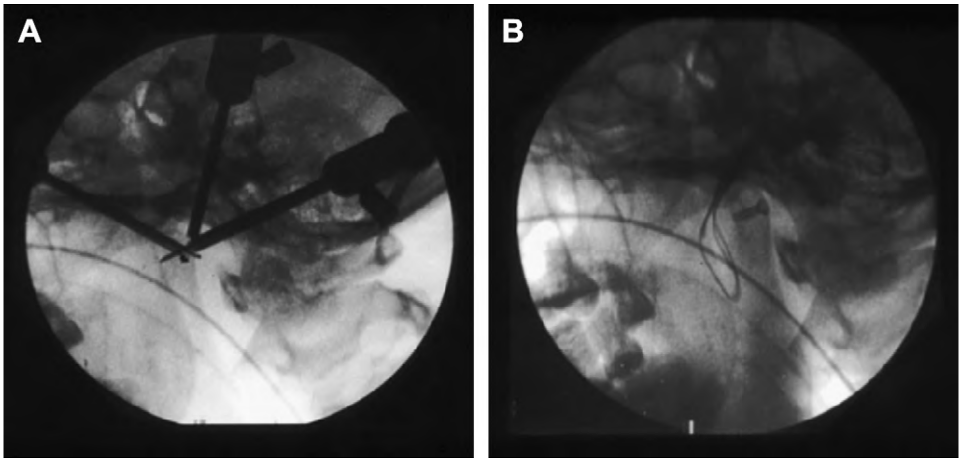

Fig. 26. Radiographic view. (*A*) Vector measuring system. (*B*) Position of fixed screw in condylar head.

Rigid discopexy has advantages because all of the work is done intraarticularly. There is much less postoperative pain. There is much less risk of facial nerve paresis, even on a temporary basis. The rigid discopexy is so secure that there is little movement of the disc or little adaptation after the procedure has been completed. Disadvantages to rigid discopexy include a postoperative malocclusion that sometimes is resistant to adaptation. Postoperative malocclusion is frequently seen because the fixation is so tight. If the joint space is inadequate or the disc is too bulky, then the postoperative malocclusion is more prominent. On many occasions, there is an adaptation of the condylar head and the disc itself so the malocclusion resolves and no further treatment is necessary. In situations, such as Wilkes stage IV disease with a small joint space and a remodeled disc, problematic malocclusion is more persistent. On occasion, an open discectomy is necessary to complete the treatment on those cases. The ideal situation for rigid disc fixation is a good joint space and well formed disc. Another potential complication is potential rejection of the screw, causing cavitation of the condylar head. This complication has been seen on occasion with resorbable screws, particularly the Inion screw. When placing rigid screw fixation, it is important that the screw is easily accessed and removed arthroscopically if in fact a problem develops with its placement.

Debridement

Arthroscopic debridement is done in cases of arthrofibrosis, synovial hyperplasia, chondromalacia stage III and IV, arthrofibrosis, and ankylosing osteoarthritis. Arthroscopic debridement is initially

Fig. 27. Exact position of the fixed screw in condylar head.

Fig. 28. Endoscopic view of fixed Inion screw within the disc.

done with a double-puncture technique, same technique, fossa portal, secondary cannula in the anterior recess. Occasionally in severe arthrofibrosis, it is not possible to get to the anterior recess, so the second puncture has to be made as far forward in the lateral sulcus as the arthroscope will advance. In any event, both an arthroscope and a working cannula must be in the joint to begin debridement. It is advisable to start debridement in the anterior recess and do as much of the debridement as efficiently as you can in the anterior recess, then work your way to the intermediate zone, and then finally the posterior pouch. An effective joint debridement is one where the instruments can pass freely from the front to the back of the joint. You have increased joint space once the debridement is completed.

Instrumentation for debridement

Manual debridement using probes can be done for Wilkes stages I and II and chondromalacia (Fig. 30).

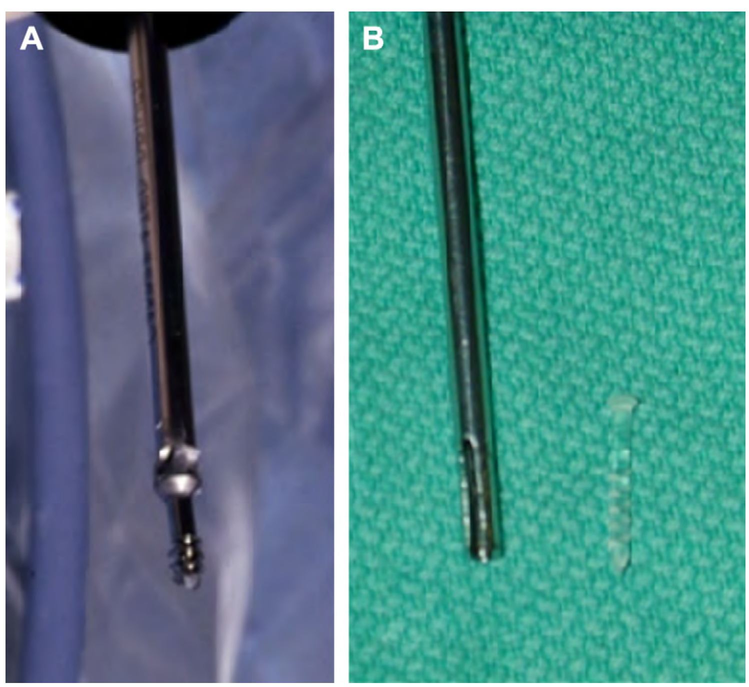

Fig. 29. Different types of screws: (*A*) metal screw, (*B*) Inion screw.

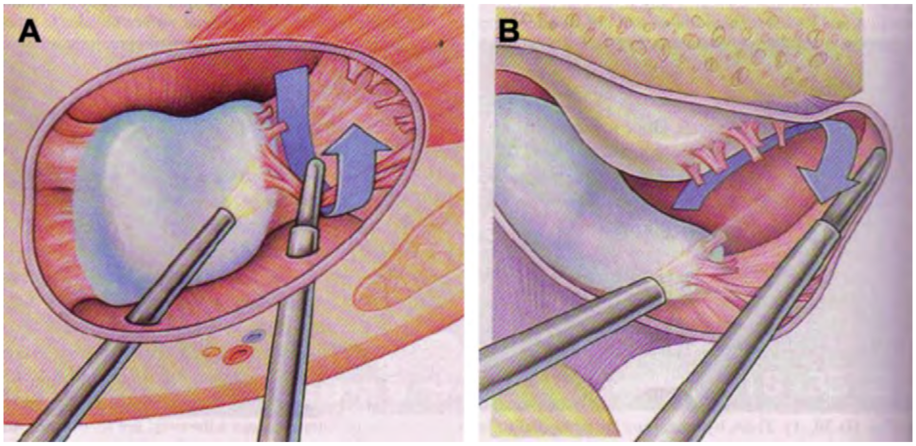

Fig. 30. Probe in the anterior recess. (*A*) Axial view showing the first medial to lateral sweep in with a downward and forward motion. (*B*) Sagittal view showing the second medial to lateral sweep is with an upward and forward motion. (*From* McCain JP. Principles and practice of temporomandibular joint arthroscopy. St Louis (MO): Mosby; 1996; with permission.)

Holmium laser or Coablation technology through a handpiece can be inserted through a 2.0-mm cannula and kept on the cut, ablation, or even weld mode for debriding of the tissue (Fig. 31). Fine stage III chondromalacia debrides well either on the weld or the ablate mode. Thicker, more fibrous tissue is somewhat resistant to laser debridement and is removed with either with a motorized shaver, a cut-biopsy forceps, or 2.4 suction punch. If a 2.4 suction punch is used, the anterior cannula needs to be switched to a 3.0 cannula rather than a 2.0 cannula. The authors' preferred motorized shaver is the 1.9 Smith & Nephew full radius shaver. The motorized shaver is used in a pawing and dabbing motion with suction so that the tissue can be drawn into the shaver piece and then as the shaver activates the suction pulls the tissue in and the shaver piece cuts off the tissue (Fig. 32). The shaver is an effective instrument to debride large bulky fibrous tissue. Additionally, other modalities for debridement include a cut biopsy forceps or, as previously stated, the 2.4 suction punch. The 2.4 suction punch is an effective instrumentation for large bulky tissue or performing partial discectomy.

In cases of perforation one attempts to do partial meniscectomy or discectomy around the areas of the perforation until there is no fragmentation of the perforation and there is no trapping of the disc in condylar motion. Abrasion arthroplasty can be completed on the fossa eminence complex of the condyle with the full radius shaver or a barrel abrader, a drill that shaves away the last little remnants of fibrocartilage and cuts into the cortical detail of the fossa eminence bone creating small microbleeds that ultimately will turn over to fibrous tissue and create a new fibrous later in the fossa eminence complex or condyle.

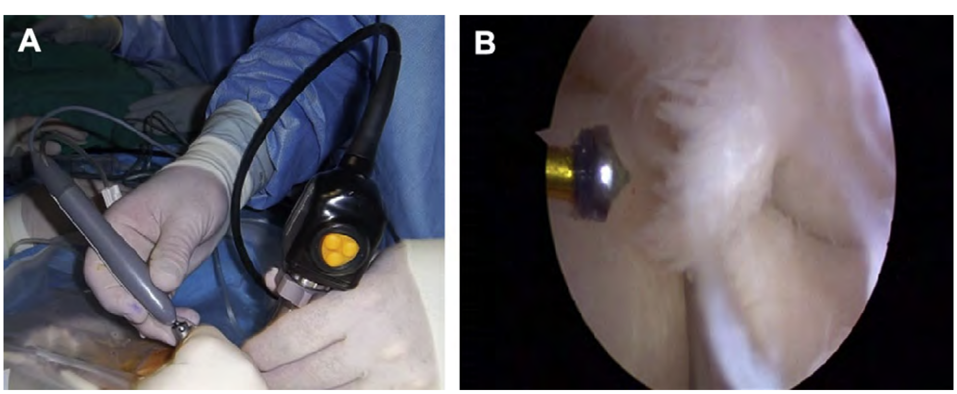

Fig. 31. Application of coablation therapy for debridement. (*A*) Position of ArthroCare handle in the working cannula. (*B*) Endoscopic view of ArthroCare tip for ablating the fibrous tissue inside the joint.

Fig. 32. Application of shaver inside the joint space to ablate fibrous adhesions.

Postoperative physical therapy in debridement cases requires a rapid return to normal range of motion. Based on Salter's work with continuous passive motion we have instituted a slow motion postoperative physical therapy program to enhance fibrocartilage regrowth and smooth surfaces.

Contracture (ARTHROSCPIC ARTHRODESIS SCARIFICATION OF RETRODISCAL TISSUES) for mandibular hypermobility or mandibular dislocation. Previous to arthroscopic techniques, mandibular dislocation needed to be handled by a form of articular eminectomy. With the advent of arthroscopy, Ohnishi developed a procedure to scar the oblique protuberance. He found that the oblique protuberance had elastic fibers in it and by scarring that oblique protuberance with the holmium laser or YAG laser scar contracture was effective to reduce the motion of the disc, which ultimately reduced the motion of the condyle and stopped dislocation (Fig. 33). The primary author has duplicated Ohnishi's technique using the holmium laser or bipolar cautery or ArthroCare. The technique is to double puncture the joint. No anterior release is necessary. The move of the instruments is back to the posterior pouch while the condyle is held in the forward position. The oblique protuberance is targeted. Lesional burns are created along the oblique protuberance from its attachment to the disc to the retrodiscal tissue. These lesional burns are both superficial and deep to effect scar contracture. One can also move laterally, and, if the synovium is redundant, superficial synovectomy is completed with the same instrumentation. The surgeon may bury the instruments into the retrodiscal tissue to enhance contracture of the posterior capsule.

Postoperatively, the primary author applies orthodontic brackets to the cuspid teeth on the buccal surfaces and then places patients into elastic physiotherapy for a period of 6 weeks (Fig. 34), essentially reversing typical physical therapy and allowing patients to only hinge open. Disc clicking can occasionally occur after this procedure. No occlusal changes are noted on this procedure. Although this has been an effective procedure to treat mandibular dislocation, eminectomy is required if failure occurs.

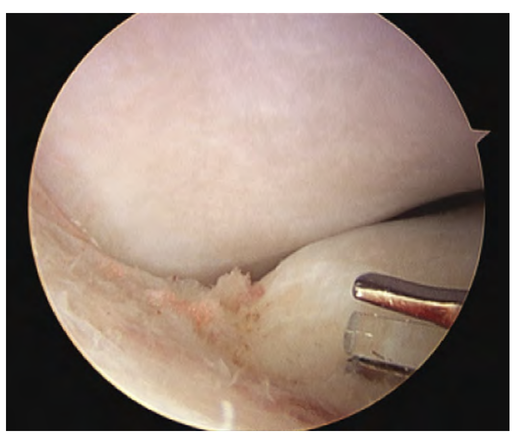

Fig. 33. Using laser tip in scarring the retrodiscal band margin to cause contracture.

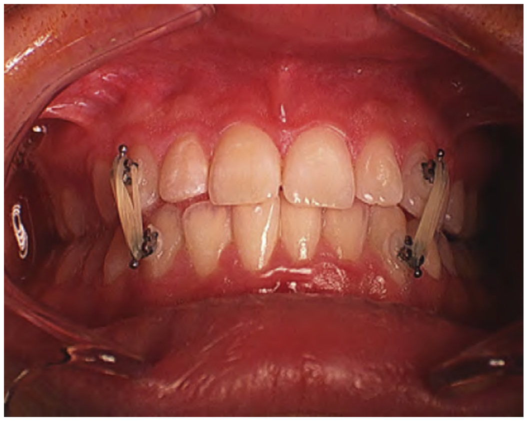

Fig. 34. Use of intermaxillary elastic fixation postoperatively after contracture procedure.

Intraarticular Medications

Steroids

Before the advent of arthroscopy, intraarticular steroids were injected via blind technique. The double-puncture arthroscopic technique, however, has made possible the injection of medications specifically targeting various anatomic articular sites. Although the primary author has a tremendous amount of firsthand experience with the use of intraarticular steroids, he does not advocate their routine administration. In the past, some benefic results have been shown in cases of marked synovitis or marked redundancy, particularly in stage III and IV medial wall synovitis. The primary author's experience and research supports the theory that medial wall synovitis is related to inflammation of the insertion of the superior head of the lateral pterygoid, which, in turn, causes restricted opening pain. The benefit of the steroid injection is the reduction of muscular irritation and spasm, thus, decreasing joint pain with function. The technique employs a 3-mL syringe with a 25-gauge spinal needle to inject a combination of 1 mL of 2 mg/mL dexamethasone and 1 mL of 6 mg/mL betamethasone.

Hyaluronic acid

This polysaccharide of the glucosaminoglycans family is a component of many extracellular tissues, including synovial fluid and cartilage. It is a product of the articular chondrocytes and synoviocytes. The concept behind TMJ injection of hyaluronate is the stimulation of the endogenous synthesis of hyaluronic acid (HA) by the exogenous HA. Hyalgan is a 500 to 730 kDa molecular weight fraction of highly purified avian sodium hyaluronate buffered (pH 6.8–7.5) in physiologic saline. The primary author thinks that hyaluronate is an excellent intraarticular lubricating agent that facilitates navigation while minimizing iatrogenic intraarticular injury (scuffing) and coagulates microbleeders in the joint.

Botulinum toxin A

As a recent modality, the positive therapeutic effect of botulinum toxin type A (Botox) on functional disorders and symptomatology in connection with the treatment of cervical dystonia is well documented. The later-years studies of von Lindern, Israel, Mendes, and others have explored local injection of Botox as a treatment method for chronic facial pain associated with hyperactivity of the masticatory muscles, with very promising outcomes. The authors are currently conducting a study on the efficacy of arthroscopically assisted direct injection of Botox into the superior head of the lateral pterygoid at the pterygoid shadow.

Complications of TMJ arthroscopic surgery

Damage to the Seventh Cranial Nerve and Facial Palsy/Atony

When approaching the TMJ for a glenoid fossa portal puncture, the frontotemporal branch of the facial nerve should be anterior, whereas for an eminence/working portal puncture, it is located posterior. However, the zygomatic branch may also be in jeopardy. In the primary author's experience, paresis of the frontotemporal branch occurs in less than 1% of procedures (reaching a high of 0.73% in the early days of arthroscopy). Invariably, these patients had undergone open arthrotomy before the minimally invasive procedure (Fig. 35).

Damage to the Collaterals of the Fifth Cranial Nerve (Auriculotemporal, Lingual, or Inferior Alveolar Paresthesia)

The auriculotemporal nerve, along with the superficial temporal artery and vein, are posterior but in proximity of the fossa puncture site. The authors' present experience has revealed that hemorrhage is uncommon and, if encountered, it is not significant and is stopped with direct pressure. Postoperative anesthesia around the entry sites is a common occurrence that spontaneously resolves within 2 weeks.

Damage to the Eighth Cranial Nerve and Vestibulocochlear Dysfunction

Tympanic membrane perforation and ossicles disruption in the middle ear has been reported, including otitis media with subsequent hypoacousia. The mechanism of entry into the middle ear is either through the osseous or soft-tissue external auditory meatus. If the tympanic membrane is perforated and the ossicles appear in the view field, immediate cessation of the procedure and intraoperative Ear, Nose, Throat/OTO-Rhino-Laryngologist consultation is warranted.

Scuffing of Fibrocartilage

The cartilage covering the eminence and fossa is most prone to iatrogeny, this being the most common arthroscopic complication. At the time of insufflation, the needle point is directed toward the posterior slope of the eminence, making contact with the fibrocartilage. Also, examination sweeps of the joint cavity, involving translation of arthroscope along with cannula, could also release pieces of cartilage into the superior joint space. If scuffing becomes significant, it impairs visibility during arthroscopic procedures to the point of misdiagnosis of chondromalacia by the inexperienced arthroscopist.

Damage to the Maxillary Artery/Collaterals With or Without Formation of Arteriovenous Fistula

As it courses medial to the condylar neck, the artery was found immediately lateral to the lateral pterygoid in two-thirds of the reviewed cases. The primary author has encountered this complication, resulting in 1 isolated case of left pterygoid arteriovenous (A-V) fistula.

Fig. 35. Patient after arthroscopic procedure on left temporomandibular joint with dysfunction of the temporofrontal branch of the seventh nerve. Note the inability to raise left eyebrow. (*From* McCain JP. Principles and practice of temporomandibular joint arthroscopy. St Louis (MO): Mosby; 1996; with permission.)

Damage to the Superficial Temporal Vessels With or Without Formation of A-V Fistula

Whether profuse or not, all cases of hemorrhage from the superficial temporal artery or vein (STA, STV) intimately related to the posterior aspect of the joint capsule were managed uneventfully by applying controlled pressure. Other investigators have reported the formation of an A-V fistula. Typically, patients complain of a constant hissing/whishing sound over the operated TMJ. The fistulectomy and subsequent embolization of the STA were uneventful.

Perforation of the Glenoid Fossa

This complication can be consistently avoided by directing the instruments toward the tubercle and away from the fossa. Most violations of the middle cranial fossa will result in cerebrospinal fluid leaks that resolve spontaneously. Should the leak persist in the wound or through the incision, a pressure dressing is applied and patients are hospitalized with head elevation. Persistence of the leak after 48 hours mandates neurosurgical consult and lumbar subarachnoid drain placement. Head computed tomography with bone windows is obtained to document the site. Surgical dural neurorrhaphy is very uncommon (Fig. 36).

Damage to the Disc

Repairs of the meniscus result in a fibrous tissue seal of the surfaces as seen arthroscopically. Core biopsies have shown minimal tissue reaction at the area of repair, consisting of fibrous cell repair with sparse vasculature. There is minimal collagen formation at the repair state and no collagen penetration or angioproliferation into the substance of the repaired meniscus. All needle punctures are filled in and smooth with the meniscus surface 12 weeks postoperatively. Exposed nonresorbable sutures are covered with translucent fibrous tissue.

Hemarthrosis

Hemarthrosis is a consequence of the laceration of the STA/STV and severely inflamed synovium/ retrodiscal tissue upon entry as well as the laceration of the pterygoid artery during myotomy for anterior release procedures.

Infection

Infection is extremely rare as a consequence of proper sterilization, a sterile operating environment, forgiving high vascular tissues, antibiotherapy, and high-volume irrigation. In fact, the primary author experienced only 1 case in his whole life. The presentation is with erythematous puncture sites with surrounding edematous halos 3 to 5 days postoperatively (Fig. 37).

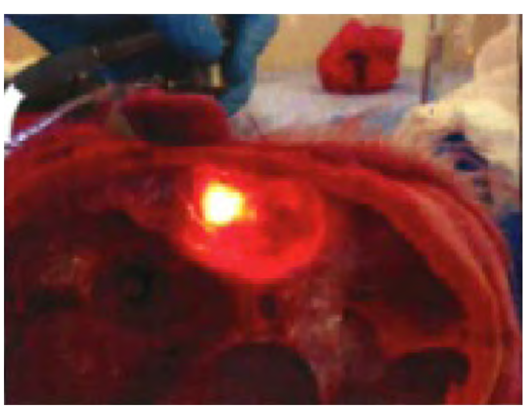

Fig. 36. Glenoid fossa perforation in cadaveric skull.

Fig. 37. Close-up of the area with purulent drainage being more evident. (*From* McCain JP. Principles and practice of temporomandibular joint arthroscopy. St Louis (MO): Mosby; 1996; with permission.)

Noninfectious Postoperative Effusions

Noninfectious postoperative effusions are present with preauricular edema, with a higher level of tenderness to palpation than normally encountered postoperatively. The patients were managed with a soft diet, joint rest, and the application of heat over the affected area. Nonsteroidal antiinflammatory drugs were prescribed as needed.

Instrument Failure/Loose Bodies

Instrument failure can be attributed to manufacturing defects, misuse and wear of parts of the instrument itself, all potentially leading to breakage. Backup instruments, including the arthroscope, are mandatory while performing arthroscopy. All instruments with flexible parts should be tested by the surgeon before introduction in the joint, including the On Point scope (Biomet Microfixation, FL, USA), trocar/cannula, scissors, biopsy forceps, and so forth.

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Modified Condylotomy for Temporomandibular Joint Dysfunction

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The modified condylotomy is an extra-articular surgical procedure used to manage patients with temporomandibular joint dysfunction. The primary purpose of the procedure is to increase joint space by allowing the mandibular condyle to move inferiorly with respect to both the articular disc and eminence (Figs 1 and 2). An additional goal in some patients is to establish a more normal condyle/disc relationship, particularly for Wilkes I, II, and III (early) internal derangements. This disc relationship can be achieved in many patients by allowing the condyle to move anteriorly in addition to inferiorly (Fig. 3).

Condylotomy may be considered in patients with intra-articular pain or locking in association with internal derangement. The procedure has also been advocated for recurrent temporomandibular joint dislocation. The main advantages of the procedure over arthroplasty are the extra-articular approach that avoids entry into the temporomandibular joint, the short duration of the procedure, and the ability to complete the surgery in an ambulatory setting. Disadvantages of the technique include the inability to address additional sources of intra-articular pain and locking, such as synovitis, fibrous adhesions, pseudowalls, osteoarthritis, chondromalacia, and synovial chondromatosis. Furthermore, patients require arch-bars and a period of elastic maxillomandibular fixation lasting 10 days to 6 weeks. A change in the occlusion following this procedure is common, although spontaneous tooth movement over time compensates adequately for the malocclusion in many patients. However, a small number of patients will need occlusal equilibration, orthodontics, or additional surgery to correct the malocclusion. The use of modified condylotomy in patients with an existing anterior open bite or a class II malocclusion is not recommended because of the potential for worsening of the anterior open bite or class II dental relationship.

Technique

The basic set of instruments required to perform a modified condylotomy includes wire twisters and wire cutters for arch-bar application; electrocautery for incision and hemostasis; a Molt periosteal elevator (No. 9) and Freer periosteal elevator for the lateral ramus and posterior border, respectively; a J-stripper for the lower border; a Woodson periosteal elevator to identify the sigmoid notch; a dental mirror to visualize the osteotomy site; a small curved osteotome and mallet to complete the osteotomy; Yankauer and Frazier suckers; a Molt mouth prop; needle holders; and a pair of Debakey forceps. The most critical instruments are Bauer retractors, Obwegeser retractors including a notched retractor, and an angled oscillating saw with a 7-mm blade. A thick ramus may occasionally necessitate a longer blade. An additional blade should be available for bilateral cases.

With the patient under general anesthesia, arch-bars are initially adapted to the maxilla and mandible from first molar to first molar using 25-gauge or 26-gauge wire. Bupivacaine 0.5% with 1:200,000 epinephrine is then injected into the soft tissues overlying the anterior aspect of the mandibular ramus. The Molt mouth prop is then inserted on the contralateral side and activated. A 5-cm incision is made

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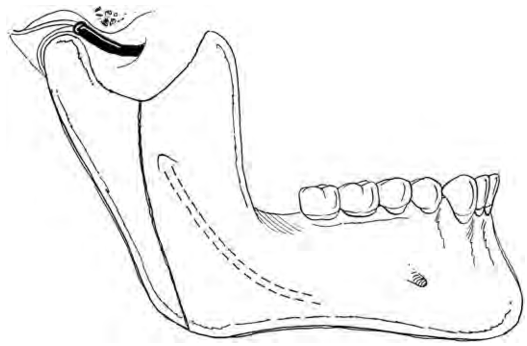

Fig. 1. Proposed osteotomy site behind the inferior alveolar neurovascular bundle.

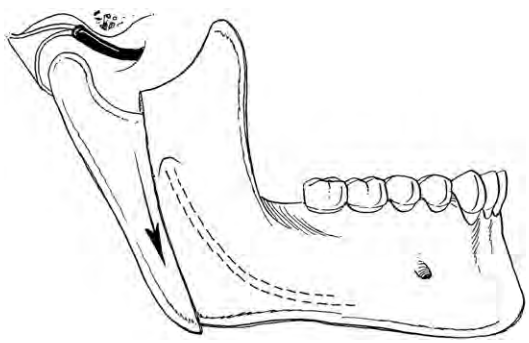

Fig. 2. Inferior movement of the proximal segment to increase joint space.

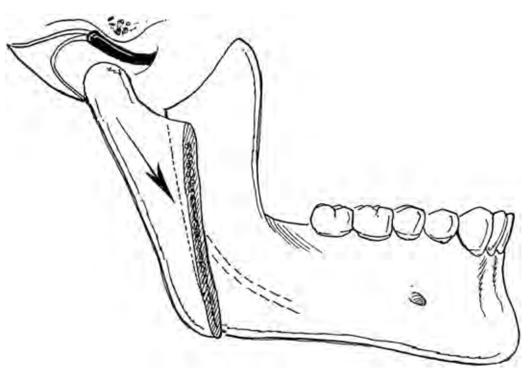

Fig. 3. Inferior and anterior movement of the proximal segment to increase joint space and reestablish a more normal relationship between the disc and condyle.

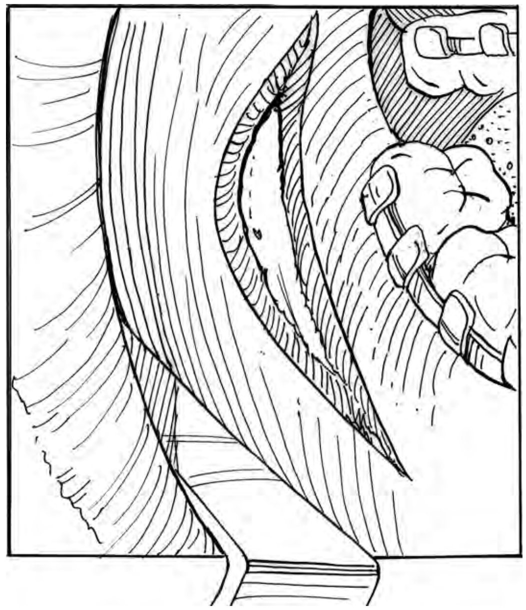

Fig. 4. Mucosal incision over the external oblique ridge and anterior ramus.

through the mucosa overlying the external oblique ridge and extended superiorly along the anterior border of the ramus of the mandible for approximately 1 cm (Fig. 4). The distal aspect of the incision proceeds through mucosa, submucosa, buccinator, and periosteum. The proximal 1 cm of the incision is through mucosa only to protect the long buccal nerve. A notched Obwegeser retractor is then used to expose the anterior ramus and dissect the inferior aspect of the temporalis tendon from the coronoid process (Fig. 5). The use of Colorado tip electrocautery during this process greatly facilitates hemostasis and temporalis muscle dissection. A Molt periosteal elevator (No. 9) is then used to develop a subperiosteal plane over the lateral ramus extending to the posterior and inferior borders. It is helpful to gently strip periosteum from the posterior and inferior border using a curved Freer elevator and J-stripper, respectively. The sigmoid notch should be identified with the use of a Woodson periosteal elevator. Bauer retractors should be placed easily in the sigmoid notch and at the lower border if adequate periosteal stripping has been performed. The antilingula and the posterior border should be easily visualized. Difficulty visualizing these areas requires further periosteal stripping.

The proposed site of the osteotomy should be identified under direct vision and with a regular dental mirror. A divergent or V-shaped orientation of the mandibular rami permits better visualization than a U-shaped orientation. It is critical that the osteotomy be positioned behind the lingula to prevent injury to the inferior alveolar neurovascular (IAN) bundle. An oscillating saw can then be used to score the lateral cortex to mark the desired osteotomy location. It is easier to begin at the mid-portion of the ramus immediately behind the IAN. The mark can then be extended inferiorly to the lower border and then superiorly to the sigmoid notch. The use of irrigation during the scoring is not needed, which greatly improves visibility. Once the osteotomy site is scored, it should be inspected with the dental mirror to ensure that it is correctly positioned. An oscillating saw with a 7-mm angled blade can then be used to complete the osteotomy by beginning at the lower border and extending the cut superiorly to the sigmoid notch (Fig. 6). When beginning at the lower border, it is advantageous to rotate the Bauer retractor at the lower border while relaxing the Bauer retractor at the sigmoid notch. Furthermore, relaxing the Molt mouth prop improves visualization of the lower border. As the sigmoid notch is approached, it is advantageous to rotate the Bauer retractor in this location and relax the Bauer retractor on the lower border to improve visualization. Gently opening the Molt mouth prop also aids in visualization of the sigmoid notch. The bone is particularly thin in this area, and care should be exercised to prevent overly deep penetration of the saw blade into the medial soft tissue when completing the superior part of the osteotomy; this can be avoided by rotating the handle of the saw so that the blade is orientated more superiorly, so that only a small area of the blade is cutting.

Once the osteotomy is complete, a periosteal elevator can be inserted into the osteotomy and the segments gently separated. Failure to complete the osteotomy is usually the result of thick bone in

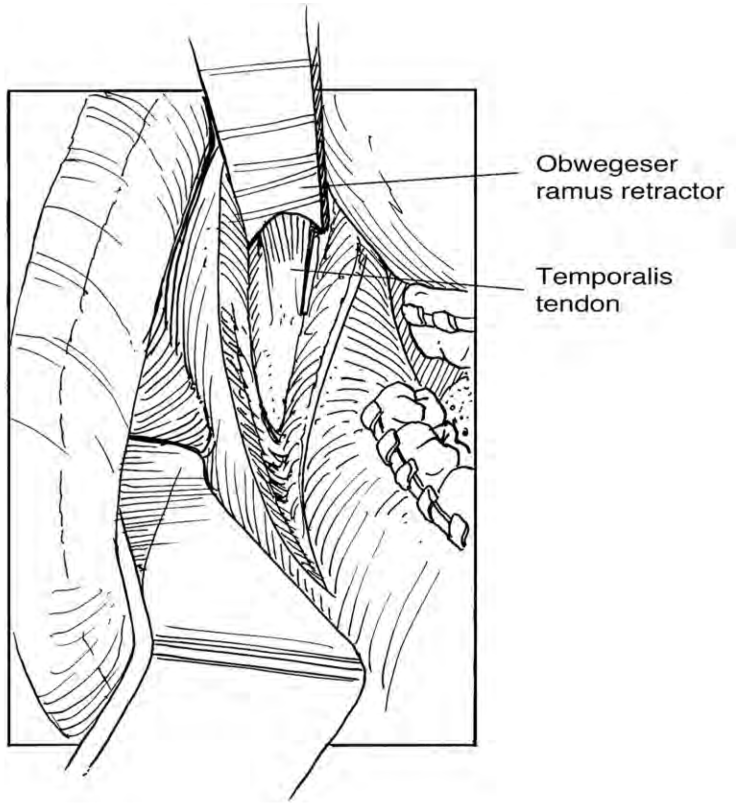

Fig. 5. Obwegeser retractor to access temporalis tendon.

the mid-portion of the ramus that may prevent the 7-mm blade from cutting completely through the medial cortex. A curved osteotome and mallet can be used to complete the osteotomy in this location if needed. The proximal segment should then be displaced laterally to verify completion of the osteotomy (Fig. 7). The wound is irrigated, and moist gauze should be placed deep in the wound to facilitate hemostasis. The procedure should be repeated on the contralateral side when indicated.

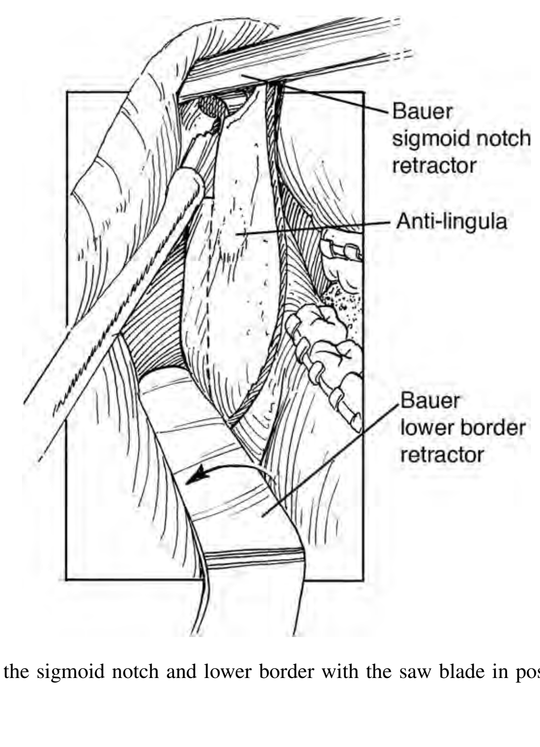

Fig. 6. Bauer retractors in the sigmoid notch and lower border with the saw blade in position behind the antilingula.

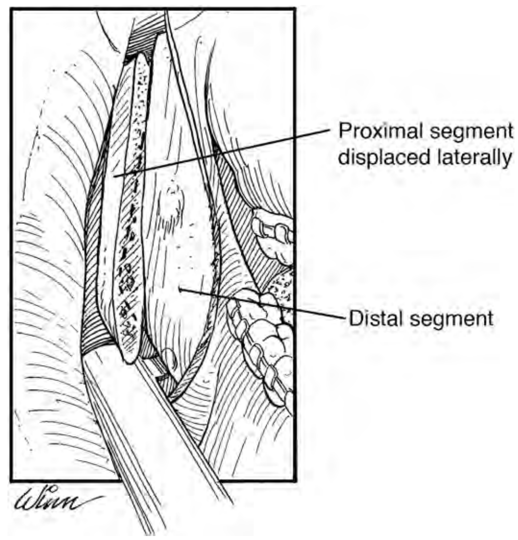

Fig. 7. Completed osteotomy and proximal segment displaced laterally with a periosteal elevator.

The throat pack should then be removed and the patient placed into maxillomandibular fixation with 26-gauge wire. The degree of condylar sag obtained can then be evaluated. A butt joint between the proximal and distal segment typically results in a 2- to 3-mm sag of the proximal segment. When anterior movement of the condyle in addition to condylar sag is desired, the surgical technique must be modified. In this situation, the inferior portion of the medial pterygoid attachment is stripped from the proximal segment and its medial aspect should be contoured. This action will allow the proximal segment to be positioned laterally to the distal segment, which permits anterior condylar movement in addition to condylar sag. Once the proximal segment is appropriately positioned, it is important to inspect the tip of the proximal segment to ensure that it does not extend past the inferior aspect of the lower border. A sharp or externally palpable tip should be removed with a rongeur or burr.

Wounds are irrigated and closed with a resorbable suture such as chromic gut. Drains are not needed. Postoperative radiographic evaluation should include a panoramic and posteroanterior view or a computed tomography scan to evaluate the degree of condylar sag and increased joint space, and to ensure that the proximal segment has formed a butt joint or is located lateral to the distal segment as planned.

Postoperative care

Maxillomandibular fixation (MMF) should be maintained for 3 weeks for unilateral procedures and 4 weeks for bilateral procedures. Periods of fixation as short as 10 days have been described but are not recommended. Transition to bilateral single light class II elastics should then be made for a period of 4 weeks, which typically results in a stable occlusion in most patients. The use of more elastics and an extended duration of elastic MMF should be considered when malocclusion is noted.

Outcomes

The majority of patients treated with a modified condylotomy report a reduction in pain and an improvement in function that seems to be independent of Wilkes classification (Figs. 8–10). Normalization of the disc/condyle relationship postoperatively appears to occur most frequently in Wilkes I, II, and III (early) internal derangements, whereas an improvement in the disc/condyle relationship is often all that can be achieved with Wilkes III (late), IV, and V internal derangements. Improvement in pain and function despite postoperative disc displacement suggest that the primary reason for success is an increase in joint space. A loss of the increased joint space over time appears to correlate with those patients in whom pain has failed to improve adequately. Repeat condylotomy has uncertain outcomes and cannot be advocated at this time.

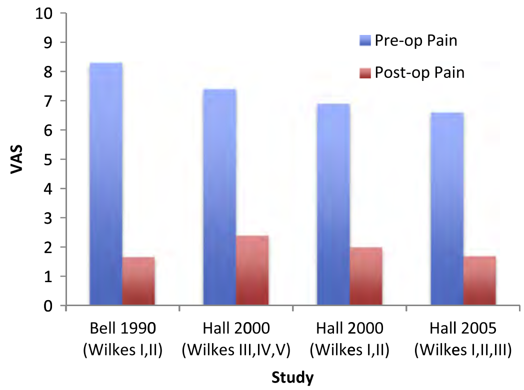

Fig. 8. Mean pain reduction following modified condylotomy.

Complications

Condylar subluxation and medial displacement of the proximal segment are exceedingly uncommon with the modified condylotomy, but require immediate reoperation to reposition the proximal segment. Wire fixation to maintain the proximal segment in the correct position may on rare occasions be needed, and can be achieved by passing a 26-gauge wire through a small hole drilled in the distal aspect of the proximal segment and securing this to a monocortical screw placed in the distal segment near the lower border. Alternatively, a small titanium plate and screws may be used to maintain the correct proximal segment position.

Significant bleeding during this procedure is uncommon. Bleeding is typically from the medial aspect of the ramus on completion of the osteotomy and is most often venous in origin. The bleeding usually responds to repositioning of the proximal segment to form a butt joint and placing gauze packing along the lateral aspect of the ramus. Arterial bleeding is rare but can be problematic when it occurs. The location of the internal maxillary artery (IMA) medial to the neck of the mandibular condyle places it at risk when the superior aspect of the osteotomy is completed. Furthermore, the masseteric branch of the IMA traverses the sigmoid notch, and is at risk from excessive retraction and while cutting the superior end of the osteotomy. Access to the IMA for control of bleeding is limited. Packing the wound followed by angiography with selective embolization of the IMA should be considered when brisk bleeding is encountered that cannot be controlled by local measures alone. Successful embolization will allow the procedure to be continued.

Malocclusion remains the most challenging complication with this procedure. The frequency of postoperative malocclusion varies enormously and varies with the degree of condylar sag, unilateral versus bilateral procedures, duration of wire MMF, duration of elastic MMF, and adaptive mechanisms of each patient. A significant number of patients will have positional changes of the mandible and increased overjet when MMF is removed. Minor tooth movement over time often compensates adequately for minor malocclusion. Occlusal equilibration is occasionally required.

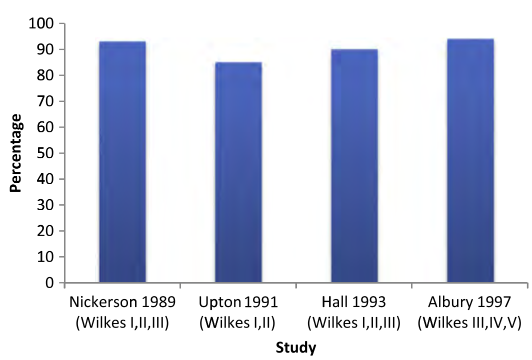

Fig. 9. Percentage of patients reporting at least a mild reduction in pain after modified condylotomy.

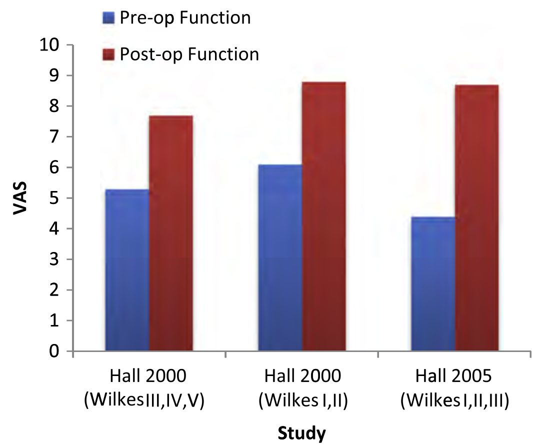

Fig. 10. Mean improvement in function after modified condylotomy.

Clinically significant malocclusion appears to be infrequent, but may necessitate orthodontic treatment or reoperation in a few select patients.

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Arthroplasty and Discectomy of the Temporomandibular Joint

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Surgery to correct disorders of the temporomandibular joint (TMJ) has been performed and documented since the mid-nineteenth century. Although earlier mentions may be found, Annandale's brief 1888 Lancet article reports a remarkably modern surgical approach to the TMJ and procedure for disc repositioning and is often cited as the first description of TMJ disc surgery. In the decades to follow, pioneering surgeons published a variety of approaches to the TMJ, traversing the preauricular area vertically, horizontally, and by various L-shaped incisions. By the mid-twentieth century, most surgeons were trained in a standard vertical preauricular approach with an anteriorly directed hockey-stick curve at the superior margin. This skin incision is often modified by extending it posteriorly so that much of its length is hidden behind the tragus (endaural approach). A less commonly used approach is to make the incision behind the ear and, reflecting the ear anteriorly and sharply transecting the external auditory canal, access the TMJ from a well-hidden postauricular approach. This article does not describe indications for open TMJ surgery and discectomy or the relative role of this treatment among others, but focuses on the surgical technique used. Once the lateral capsule is reached, any of the open joint procedures described in this text may proceed, but this article describes a conservative discectomy without disc reconstruction. The following description uses a standard preauricular incision and dissection as performed by the author based on the collective experience and wisdom of many surgeons before him.

Patient preparation

Although case reports document open TMJ surgery under local anesthesia, most of these operations are performed under general anesthesia with the patient supine and head turned to expose the side to be operated. Worldwide, increased attention has recently been given to protocols enhancing patient safety, including checks to minimize the risk of wrong-side surgery. Because TMJ disease rarely shows obvious localizing external signs, the prudent surgeon makes full use of such routines to ensure that the correct joint is prepared for surgery. Postsurgical infections are exceedingly rare following TMJ surgery, and it is usually not necessary to clip hair in the surgical field unless it will be bothersome or enter the wound during surgery. Surgical antibiotic prophylaxis is generally used according to local guidelines and the surgeon's discretion. Before prepping skin, an antibiotic ointment–impregnated cotton or gauze plug is gently inserted into the external auditory canal to minimize fluid entry during surgery, which could otherwise lead to postoperative irritation and pain of the canal or tympanic membrane. Contemporary surgical literature supports the use of chlorhexidine solutions to prep skin for incisions, but, because of its risk of eye injury, we use Betadine to prepare the external ear and preauricular area superiorly to several centimeters above the zygomatic arch, anteriorly to the lateral canthus of the eye, and inferiorly to the mandibular border. A smaller area

The author has nothing to disclose.

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is then surrounded with sterile drapes, leaving the ear exposed. A sterile adhesive barrier may be applied as well. However, like many widely practiced routines intended to prevent infection, this measure has little or no scientific evidence supporting routine use for TMJ procedures. Additional measures routinely endorsed for other orthopedic procedures, such as laminar flow operating rooms or spacesuits for operating room personnel, do not seem to further reduce the already-low infection rate for head and neck surgery.

Surgical anatomy

The preauricular approach to the TMJ passes through an area bounded posteriorly by the external ear and anterior wall of the external auditory canal, inferiorly by the main trunk of the facial nerve and the parotid gland, and anteriorly by the path of the temporal (frontal) branch of the facial nerve. The superior boundary of the space is more variable, and it is this direction in which dissection may be extended when additional access is needed. Within this space, the auriculotemporal nerve and superficial temporal artery and vein run inferiorly to superiorly, anterior to the ear and within the subcutaneous loose connective tissue superficial to the superficial temporal fascia (Fig. 1). These vessels may usually be retracted anteriorly as dissection proceeds, although they often possess small posterior tributaries or branches that must be cauterized or ligated and divided.

The course of the facial nerve and its branches (Fig. 2) must be known to avoid violating the boundaries of safe surgery and creating a potentially paralyzing injury. In their landmark 1979 article, Al-Kayat and Bramley measured the location of the facial nerve's main trunk and found that it runs no nearer than 1.5 cm below the inferior margin of the bony external auditory meatus and that the most posterior temporal branch of the nerve crosses the zygomatic arch anterior to the bony external auditory meatus at a minimum distance of 0.8 cm and mean of 2.0 cm. Similar cadaver studies by Woltmann found a minimum distance of 0.7 cm and a mean of 1.5 cm, whereas an elegant high-resolution MRI study of live subjects by Miloro and others measured a minimum distance of 1.7 cm and mean of 2.1 cm (Fig. 3). Agarwal and others made a significant addition to the knowledge of the facial nerve's path in 3 dimensions by showing in an anatomic study that the temporal branch lies in the loose areolar connective tissue layer between the superficial and deep temporal fascia as it crosses the zygomatic arch; it enters the superficial temporal fascia from its undersurface in a consistent region 1.5 to 3.0 cm above the zygomatic arch and 0.9 to 1.4 cm posterior to the lateral orbital rim (Fig. 4).

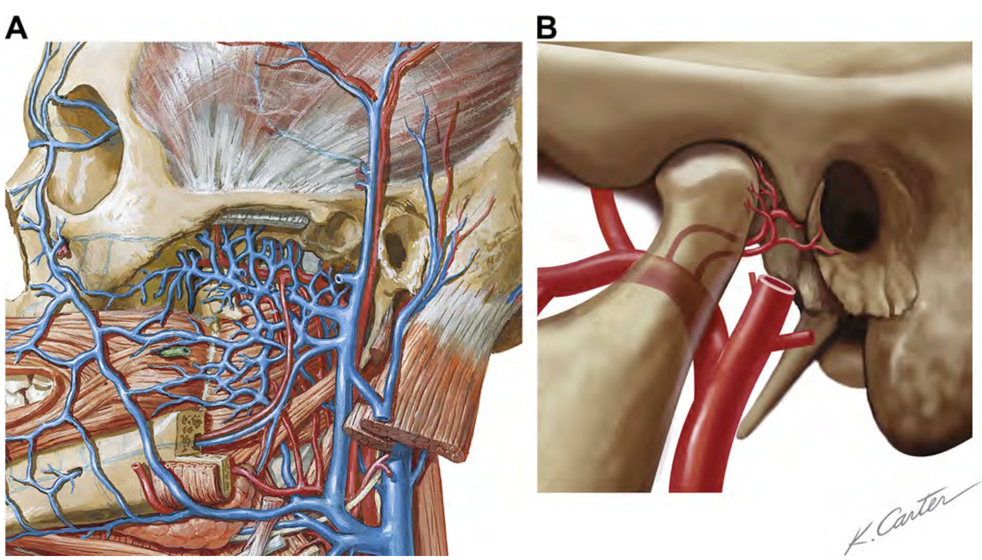

Fig. 1. Major blood vessels traversing the preauricular area. (*A*) Superficial temporal artery and vein superficial to the TMJ and just anterior to the ear. (*B*) Small arteries supplying the TMJ approach from the posterolateral direction. (Netter illustrations available at: www.netterimages.com. Elsevier Inc. All rights reserved; with permission.)

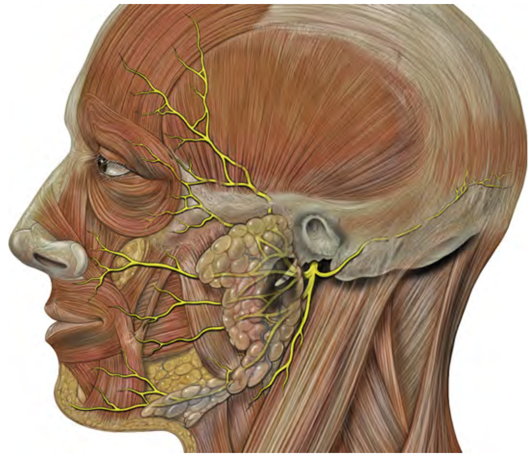

Fig. 2. Facial nerve branches. (*Courtesy of* Patrick J. Lynch, medical illustrator; C. Carl Jaffe, MD, cardiologist, Yale University School of Medicine, Center for Advanced Instructional Media, New Haven (CT). Published under Creative Commons Attribution 2.5 License 2006. http://creativecommons.org/licenses/by/2.5/.)

Skin incision

The intended skin incision line is drawn (Fig. 5) by making use of any previous incision scars or strategically located fine skin wrinkles. One advantage of the preauricular approach is that it preserves the natural projection of the tragus if placed just slightly (about 1–2 mm) anterior to the junction of the tragus and preauricular skin surface. The incision extends inferior to the tragus by no more than a few millimeters and superiorly in an anteriorly directed curve to a point approximately 1 cm above the superior margin of the palpable zygomatic arch. In cases requiring broad anterior exposure of the zygomatic arch and articular eminence, or if a temporal muscle flap will be used in joint reconstruction, the incision may be extended superiorly as needed with little additional morbidity to gain the necessary access. However, it is not routinely necessary to make a longer incision than first described to access the lateral capsule and articular eminence. Many surgeons carry the midportion of the skin incision posterior to the margin of the tragus, which hides that part of the scar from anterior or lateral view. If this is done, care must be taken when closing the wound to securely reapproximate the subcutaneous tissues at the base of the tragus and not allow this attachment to migrate superficially onto the surface of the tragus itself. Otherwise, the pretragal skin angle will be flattened and the patient will appear to have no tragus. Before the incision is made, local anesthetic with vasoconstrictor may be injected into the skin along the planned incision line as well as into the TMJ itself.

Once the skin incision is made, the avascular plane immediately anterior to the perichondrium of the external auditory canal wall's anterior surface is opened bluntly, beginning just deep to skin at the base of the tragus. Once the cartilage surface is located, the dissection must be directed medially and

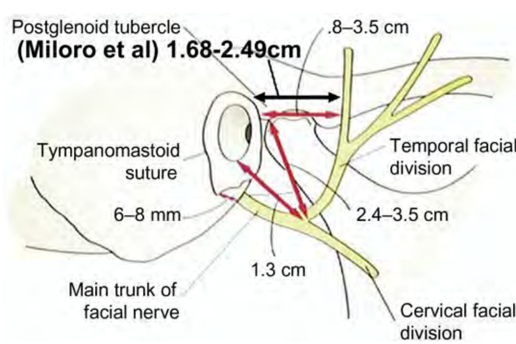

Fig. 3. Distance between external auditory canal and temporal (frontal) branch of facial nerve. (*From* Miloro M, Redlinger S, Pennington DM, et al. In situ location of the temporal branch of the facial nerve. J Oral Maxillofac Surg 2007;65(12):2469; with permission.)

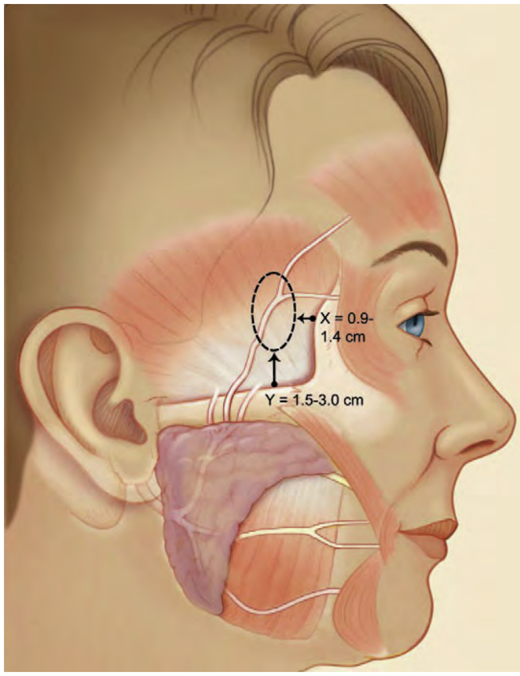

Fig. 4. Area in which the temporal (frontal) branch of the facial nerve transitions from lying deep in the superficial temporal fascia to piercing it from below. (*From* Agarwal CA, Mendenhall SD, Foreman KB, et al. The course of the frontal branch of the facial nerve in relation to fascial planes: an anatomic study. Plast Reconstr Surg 2010;125(2):535; with permission.)

anteriorly, not perpendicular to the skin surface, to follow the path of the auditory canal cartilage and avoid injury to the ear. Scissors with blunt outer edges, such as a small Metzenbaum scissors, work well for this dissection in previously unoperated cases, but sharper-tipped scissors such as tenotomy or iris scissors are often needed to dissect through scarring from previous operations. When in the correct plane, this initial dissection creates a clean, bloodless pocket immediately anterior to the tragus that ends bluntly at the depth of the parotidomasseteric fascia (Fig. 6). There is little resistance to opening this tissue plane until the correct depth is reached, at which point the prudent surgeon stops until having better exposure of the deep area. Further attempts to deepen the wound at this time may result in inadvertent entry into the auditory canal or middle ear and must be avoided.

Fig. 5. Preauricular skin incision line. Many surgeons prefer an endaural incision placed at variable distances posterior to the dotted line where it is less visible.

Fig. 6. Initial dissection just anterior to the perichondrium of the anterior surface of the external auditory canal wall.

Next, attention is directed to the superior portion of the skin incision where a second blunt dissection opens the subcutaneous tissues lying over the superficial temporalis fascia (Fig. 7). If the superficial temporal vein or artery is encountered (Fig. 8A), it can usually be retracted anteriorly using a Senn retractor. Dissection continues through the superficial temporal fascia until the smooth, white, well-defined surface of the deep temporal fascia is exposed (see Fig. 8B). A second Senn retractor is then returned to the pretragal dissection (see Fig. 8C). At this point, with the course and depth of the wound clearly defined by easily identified landmarks, the soft tissue isolated between the 2 retractors is released sharply using scissors, following the same medial and anteriorly directed plane determined by the auditory canal cartilage (see Fig. 8D). Small blood vessels in this area may be cauterized with fine-tipped bipolar cautery. Dissection continues deeply until the zygomatic arch is

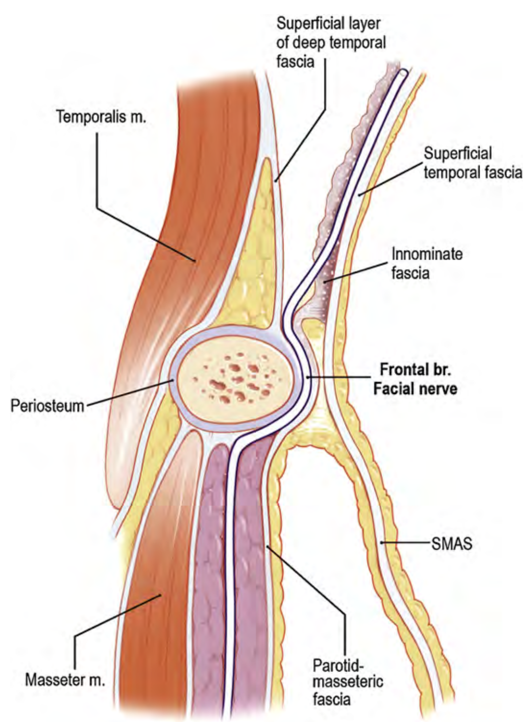

Fig. 7. Frontal diagram showing the tissue planes superficial and slightly anterior to the TMJ. The central bony structure is the cut end of the zygomatic arch. (*From* Agarwal CA, Mendenhall SD, Foreman KB, et al. The course of the frontal branch of the facial nerve in relation to fascial planes: an anatomic study. Plast Reconstr Surg 2010;125(2):536; with permission.)

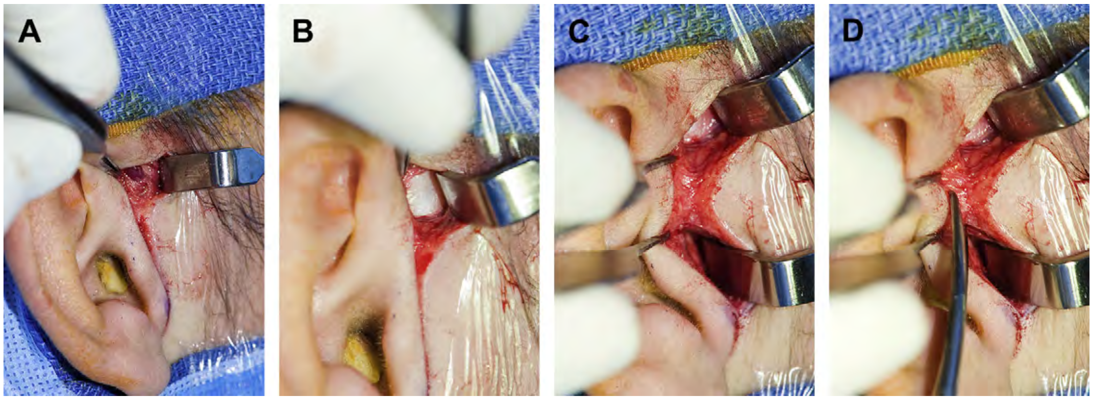

Fig. 8. Dissection to the superficial temporal fascia. (*A*) Exposure of the superficial temporal vein, which may be retracted anteriorly. (*B*) Clean white surface of the superficial temporal fascia. (*C*) Senn retractors in each soft tissue pocket, delineating tissue to be sharply dissected. Identifying these landmarks allows safe clean dissection to the necessary plane. (*D*) Sharp dissection of the remaining soft tissues following the established plane.

palpable under the superficial layer of the deep temporal fascia, which divides 1 to 2 cm above the arch to surround it. The tissues anterior and superficial to this plane are retracted gently to minimize any traction on the temporal branch of the facial nerve, and only a narrow band of the fascia over the zygomatic arch is exposed just superior to the auditory canal cartilage and connecting the 2 initial dissections.

A scalpel blade is then used to make an incision in the superficial layer of the deep temporal fascia in the same plane as the dissection to expose the area, beginning about 1 cm above the zygomatic arch. In most cases, a thin layer of fat and small blood vessels is encountered, confirming the correct location and depth (Fig. 9A). The incision is then extended inferiorly across the zygomatic arch, pressing firmly on the bone but taking care to avoid penetration of the muscle above the arch or posterolateral capsule area of the TMJ below, because both these areas are prone to bleeding. A Molt periosteal elevator is then used to dissect under the periosteum anteriorly, which takes the dissection below the superficial layer of the deep temporal fascia; retracting from beneath this layer protects and retracts branches of the facial nerve. The incision in the deep temporal fascia may be extended superiorly if needed to improve access, but usually the tissue attachments that limit anterior retraction along the zygomatic arch are inferior to the arch over the lateral capsule of the TMJ.

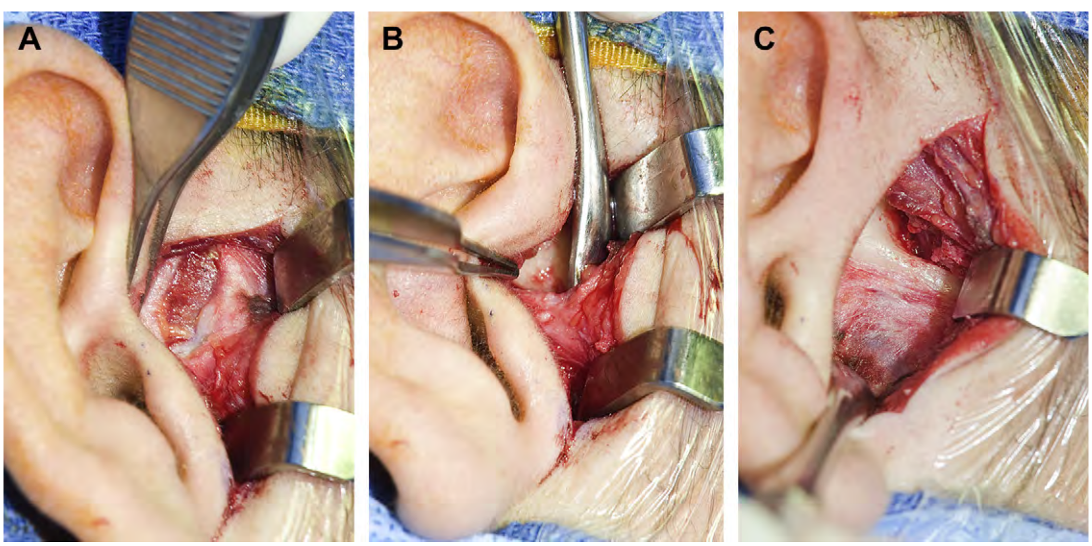

Fig. 9. Exposure of the lateral capsule. (*A*) Incision through the superficial temporal fascia, just anterior to the plane of dissection and parallel to the skin incision. In this thin patient, little fat is seen deep to the fascia. (*B*) Subperiosteal dissection along the lateral surface of the zygomatic arch, which identifies the parotidomasseteric fascia covering the TMJ capsule. (*C*) View of the lateral capsule following sharp release of the parotidomasseteric fascia along the original plane of dissection.

Dissecting in the safe plane under the periosteum anteriorly and slightly inferiorly defines the plane just superior to the lateral capsule of the TMJ and the posterior attachment of the overlying parotidomasseteric fascia (see Fig. 9B). This posterior attachment may be carefully cut just anterior to the auditory canal wall and the fascia retracted anteriorly to expose the lateral capsule to view (see Fig. 9C). The sharp dissection should extend no farther than necessary beyond the inferior margin of the auditory canal cartilage to avoid troublesome bleeding or, with still farther inferior dissection, potential injury to the facial nerve.

With the lateral capsule now well exposed, the joint area is palpated to verify the location of the lateral pole of the condyle. The joint is entered by making an initial incision of 4 to 5 mm through the capsule that is parallel to and 2 to 3 mm below the inferior border of the zygomatic arch (Fig. 10A) and superior to the lateral pole of the condyle. If local anesthesia was successfully injected into the superior joint space earlier, it will now flow out from this incision, verifying entry into the joint space. A Freer elevator is introduced through the incision and used to gently sweep across and define the superior joint space, releasing adhesions between retrodiscal tissue and disc and the glenoid fossa and articular eminence. At this point, the superior surface of the retrodiscal tissue and disc is visible below the superior articular surfaces. The Freer elevator is then turned vertically and directed through the capsular incision inferiorly, just lateral to the lateral pole of the condyle and deep to the capsule, to define the lateral recess (see Fig. 10B). A vertical incision is then made with the elevator in place, completing a T-shaped capsular opening and exposing the superior joint space and lateral attachment of the disc to the condyle (see Fig. 10C). The lateral attachment of the disc may be grasped with a toothed Adson forceps to allow inspection of the superior disc surface and assess its mobility.

If the disc will be removed, the inferior joint space must be entered by dissecting through the lateral attachment of the disc. Removal may be accomplished by blunt dissection with sharp-tipped scissors (such as iris scissors) or by making a short stab incision with a #15 scalpel blade, taking care to avoid injury to the underlying articular cartilage covering the condyle (Fig. 11). Again, a small Freer elevator is used to sweep through and define the inferior joint space and locate the lateral pole of the condyle.

At this point, the upper and lower compartments of the TMJ are open and the disc is partially dissected free from the lateral side. Depending on the morphology and mobility of the individual joint, there may be adequate space to allow vision and access to the anterior and medial areas. In other cases, inferior distraction of the condyle is necessary to gain the access needed. This access is easily acquired through use of a Wilkes joint distractor (Fig. 12, KLS-Martin LP, Jacksonville, FL, USA), which is secured by placing 2 parallel 0.062-inches (1.57-mm) Kirschner wires in the zygomatic arch and the condyle.

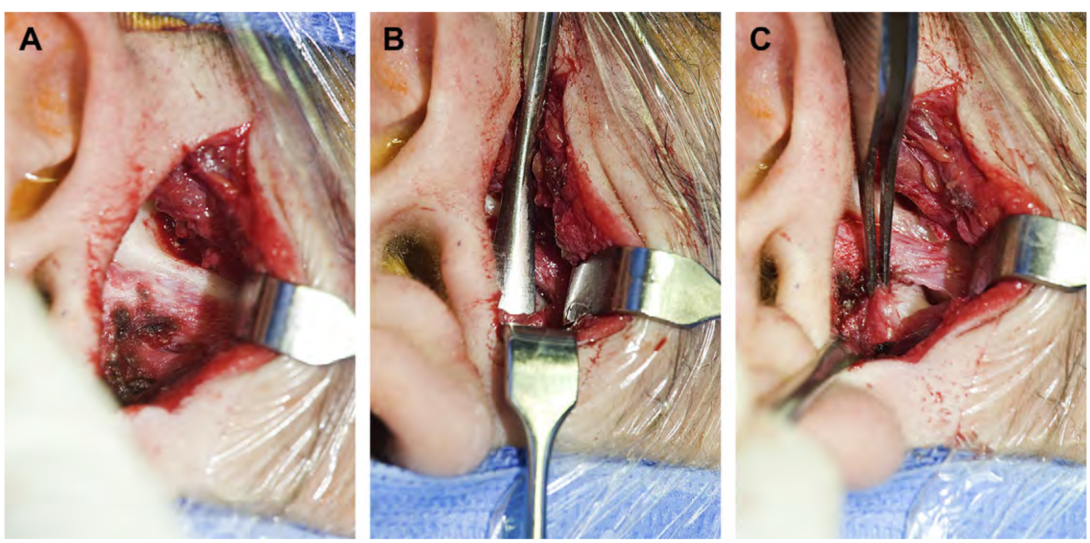

Fig. 10. Entry through the lateral capsule of the TMJ. (*A*) Initial incision 2 to 3 mm below and parallel to the inferior margin of the zygomatic arch. Fine-tipped bipolar cautery has been used to control small bleeding vessels. (*B*) A Freer elevator is inserted vertically under the lateral capsule to define the superior lateral recess and location of the vertical incision through the capsule. (*C*) Grasping the lateral attachment of the disc.

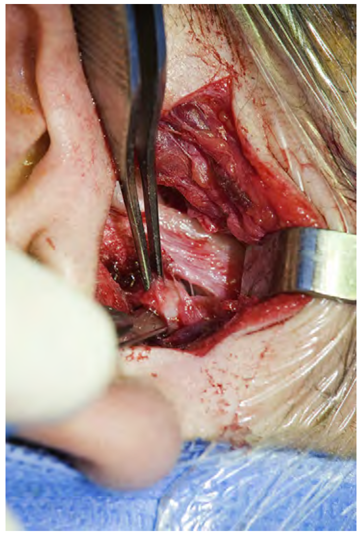

Fig. 11. The disc is held in place while a horizontal incision is made through its lateral attachment to enter the inferior joint space.

Removal of the disc proceeds by first extending the release at the lateral attachment anteriorly and then medially, using sharp scissors or a scalpel blade as necessary. As this attachment is released, it is often possible to open the Wilkes retractor wider, improving access to both the disc's attachment to retrodiscal tissue and the anteromedial area of the joint. Care is taken to minimize injury to the retro-discal tissue, which is usually hyperemic. Once this tissue starts oozing, it is difficult to stop the bleeding without extensive cauterization and destruction of essential synovial tissue. Similarly, blind cutting at the disc's anteromedial attachment can lead to muscle bleeding from deep in the joint, which obscures vision and is difficult to stop with the joint held open or distracted. Depending on joint and disc morphology, it may be prudent to remove the disc in several pieces starting from the most lateral and accessible part, then proceeding deeper into the joint with improved vision and access (Fig. 13).

With the disc removed and hemostasis achieved, the joint surfaces are inspected and any irregular areas surfaces removed with a fine rasp if needed. Although large irregular fragments of loose

Fig. 12. Wilkes joint retractor. Turning the large knob spreads the limbs of the retractor, which, when secured to the zygomatic arch and condylar neck, distracts the condyle inferiorly without obscuring vision into the joint or making a separate incision. (*Courtesy of* KLS-Martin LP, Jacksonville (FL); with permission.)

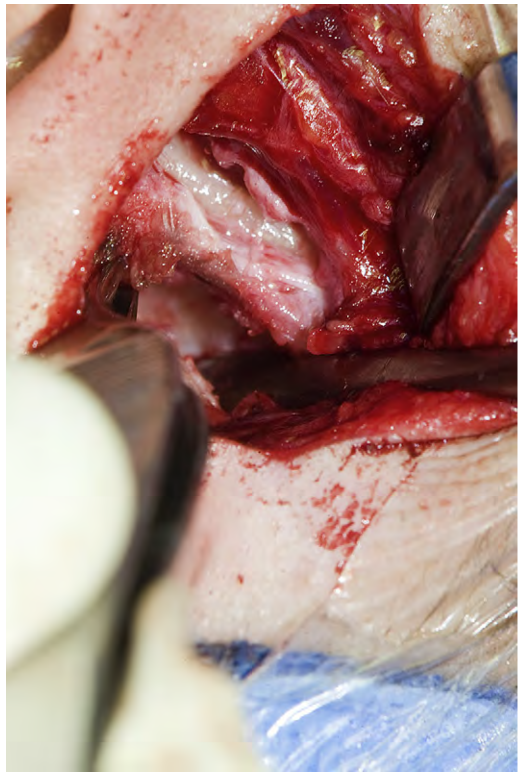

Fig. 13. With the lateral part of the disc removed, the remaining disc and joint surfaces are more easily inspected.

cartilage may be removed, it is desirable to preserve as much fibrocartilage cover over articular surfaces as possible. Large osteophytes may be reduced, if present. In many cases, the retrodiscal synovium has adhered to the posterior superior joint surface and may be freed by gently scraping the joint surface from anterior to posterior with a smooth-edged elevator. If an autogenous graft will be placed, this is now performed. Otherwise, the joint is irrigated and the wound closed. The T-incision in the capsule is closed using a slowly resorbing suture on a small needle (Fig. 14A, B). Next, the superficial layer of the deep temporal fascia is closed (see Fig. 14C). The deep portion of the soft tissue overlying the posterior root of the zygomatic arch is reapproximated with an interrupted suture, placing the suture as close to the bone as possible in the soft tissue just superior to the auditory canal wall. Several additional deep sutures are placed in the subcutaneous tissue, and the skin is closed according to surgeon preference. The skin margins should meet passively because there should be no tension on the incision line (see Fig. 14D). If a nonresorbable running cutaneous suture is used (see Fig. 14E) and postsurgical edema is minimal, it may be removed as early as postoperative day 4 or 5 because tension along the skin incision is negligible. This technique minimizes crosshatching that might otherwise develop in the skin scar. The wound may be dressed with antibiotic ointment or, if deemed necessary, with a pressure dressing head wrap or Jobst elastic wrap (BSN-Jobst, Rutherford College, NC, USA).

Postoperative care

If a pressure dressing is used, it may be removed the next morning. The patient is instructed to keep the incision dry and apply antibiotic ointment lightly twice a day until sutures are removed. A soft, no-chew diet is prescribed for 2 to 3 weeks in most cases; then, the texture may be advanced cautiously as tolerated. After the initial 3 or 4 days, the patient begins gentle range-of-motion exercises several times a day. Formal physical therapy may be prescribed with the goals of early improvement in range of motion and mobilizing postsurgical edema. However, many well-motivated patients recovering from repair of a mechanical joint dysfunction are able to quickly restore normal range of motion and achieve low pain levels on a course of home therapy as outlined earlier.

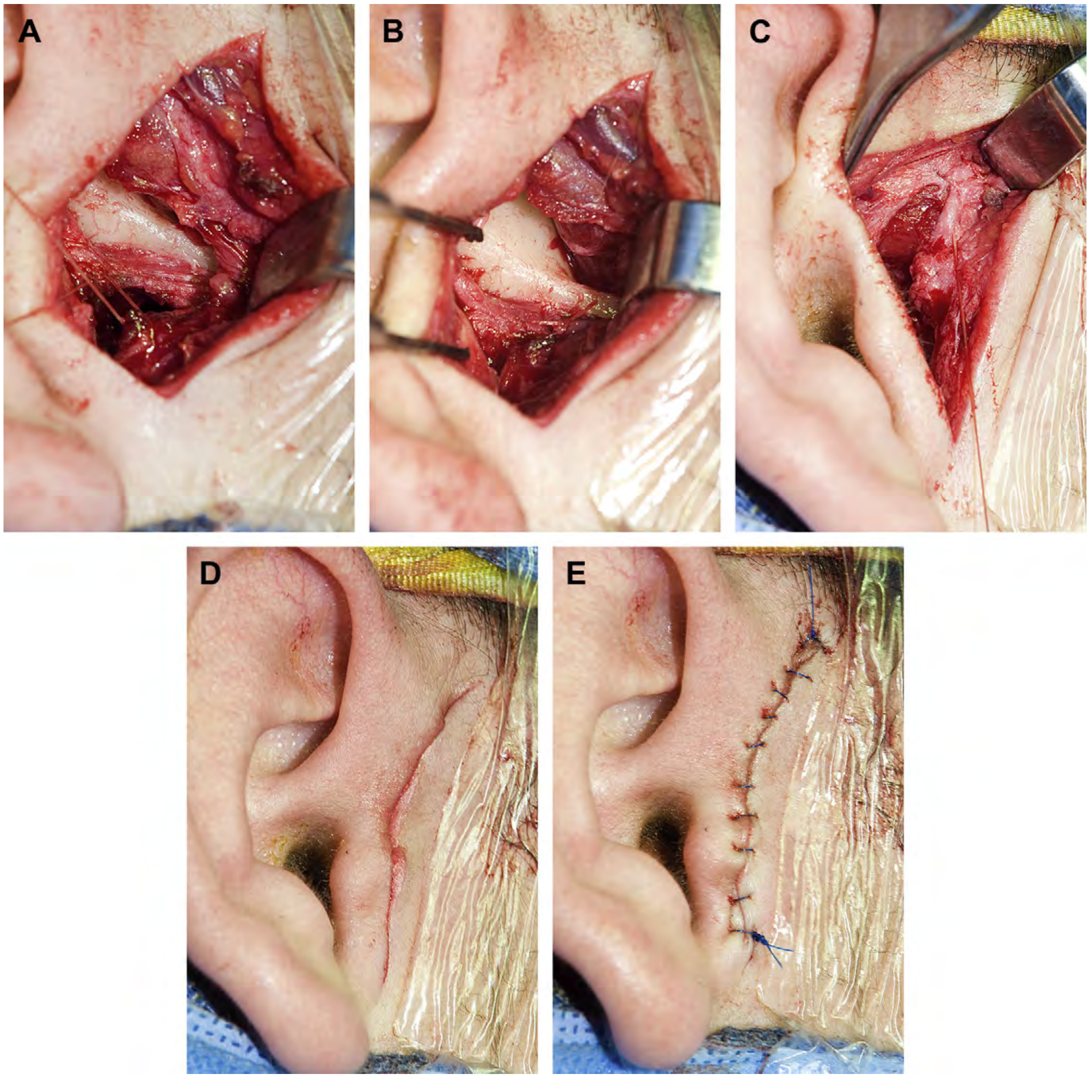

Fig. 14. Wound closure. (*A*) Sutures passed through the corners of the lateral capsule and cuff of capsular tissue remaining attached to zygomatic arch permit tight closure. (*B*) Capsule is closed; note intact superficial temporal vein in superior part of dissection. (*C*) Superficial temporal fascia is ready to close with a running suture. (*D*) Tension-free skin margins following subcutaneous suturing. (*E*) Running suture to reapproximate skin.

Summary

Many operations to correct TMJ conditions are available to the contemporary surgeon. The surgical approach to the TMJ described here is a well-established and efficient means to access the joint for most of these operations, starting with a conservative dissection but modifying the incision length and design where necessary. The resultant scar from a well-managed wound is unobtrusive despite its location on the face. Like all tools, TMJ arthroplasty and discectomy must be used correctly, for the proper purpose, and in the proper conditions to achieve the desired outcomes.

Further readings

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Temporomandibular Joint Eminectomy for Recurrent Dislocation

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Recurrent mandibular dislocation

Since the days of Hippocrates, repositioning of the dislocated mandible has been an important topic in medicine and dentistry, and the first surgical techniques for the prevention of recurrent mandibular dislocation and for the treatment of long standing luxation were described in the late 1800s.

Dislocation of the mandible is usually bilateral. The symptoms are open mouth, protruding chin, tense masticatory muscles, salivation, speech difficulties, and pain. In unilateral cases, the mandible deviates toward the opposite side from the dislocated condyle. On manual palpation, the glenoid fossa is empty, and the condylar head can be palpated anterior to the eminence.

Some investigators have defined normal maximum translation of the condyle as the point at which the greatest convexity of the condyle meets the greatest convexity of the articular eminence. About 60% of normal subjects translate more anterior to that point without any symptoms. Subluxation occurs when the condyle translates anterior to its normal range, and the patient exhibits a temporary locking or sticking sensation that either abates spontaneously or can be reduced with self-manipulation (Fig. 1). Dislocation is a more advanced hypertranslation in which the condyle locks anterior to the eminence in a position that cannot be self-reduced because the condyle is fixed in that position by muscular spasm (Fig. 2). This state requires medical assistance to relocate the condyle in its normal position. In some cases, periarticular application of local anesthetics or tranquilizer premedication is necessary before manual reduction of the mandible is possible.

Recurrent mandibular dislocation is uncommon. Boering found an incidence of 1.8% in a population of 400 patients with symptomatic temporomandibular joint (TMJ) disorders. Recurrent mandibular dislocation is found more frequently in people with general joint laxity and in patients with internal derangement of the TMJ or with occlusal disturbances, such as loss of teeth and vertical height. It may be associated with neurologic diseases encountering increased muscular activity or tension as well as in patients suffering from extrapyramidal symptoms who are receiving neuroleptic therapy. Recurrent dislocation of the condyle may cause injury to the disc, the capsule, and the ligaments, leading to progressive TMJ internal derangement.

Conservative treatment modalities and indications for surgery

The rationale for operative intervention is often influenced by the duration of the patient's symptoms and the exhaustion of other forms of treatment. Conservative treatment includes physiotherapy, training the muscles to avoid excessive translation of the condyles, and prosthetic restoration of vertical height. Following an acute dislocation, immobilization of the jaw in the closed position for some days to some weeks has been advocated. For edentulous patients with repeated luxations, wearing their prostheses during the night has been successfully recommended. In patients with extrapyramidal motor disorders,

The author has nothing to disclose.

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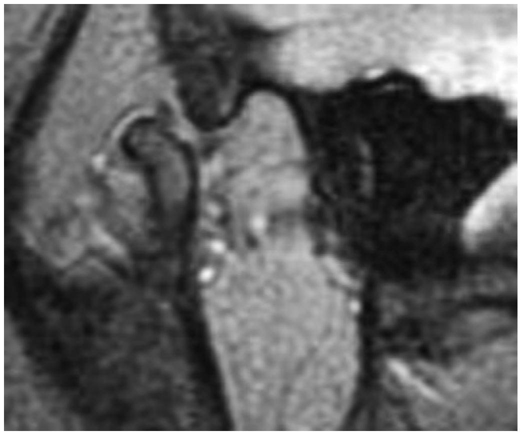

Fig. 1. Parasagittal magnetic resonance imaging (MRI) of a patient with subluxation. The condyle translates far anterior to the eminence, whereas the disc is in a posterior position relative to the condylar head.

like Parkinson disease, or patients taking neuroleptic medication, modifications in drug therapy should be tried before indicating invasive therapies. In our opinion, surgical therapy is only indicated when all available conservative treatment methods have failed.

Injection of sclerosing agents and botulinum toxin A

More invasive therapies like periarticular and intraarticular application of sclerosing agents or autologous blood are still considered conservative management of recurrent mandibular dislocation by some investigators. In our opinion, this is not the case because these procedures are designed to provoke capsular fibrosis and to create intraarticular adhesions. The first report of periarticular alcohol injection was by Hacker in 1884 (cited by Myrhaug 1951). Since then, many investigators have reported injections of various substances, such as iodine solution (Genzmer 1889) or sodium psylliate (Schultz 1937), into or around the temporomandibular joint. Injection of autologous blood

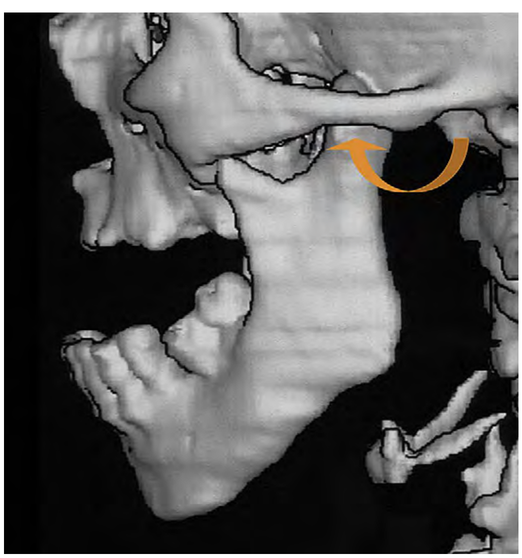

Fig. 2. Three-dimensional computed tomography (CT) scan of a patient with true mandibular dislocation. The condyle locks anterior to the eminence, fixed in that position by muscular spasm. The articular surfaces are completely separated. The yellow arrow indicates the path of the condylar head from its normal position in the glenoid fossa to the dislocated postion in the infratemporal fossa.

was first described by Brachmann (1964). Several of the reports on intraarticular and periarticular injections indicate that these treatments must be repeated in some cases to gain the desired effect.

Single or repeated injections of botulinum toxin A into the lateral pterygoid muscle, with or without electromyographic guidance, have been advocated by Daelen and colleagues (1997). Botulinum toxin A weakens the lateral pterygoid muscle selectively and thus can correct the muscular imbalance that is causing recurrent dislocation.

Surgical treatment of recurrent mandibular dislocation

Various surgical methods have been advocated for the treatment of recurrent mandibular dislocation. There are many ways to limit excessive translation of the condyle and, thus, a great variety of techniques are recommended for this purpose.

Articular Disc Surgeries

Annandale was the first to report surgical reduction of the displaced articular discs in 2 female patients in 1887. One of the patients suffered from unilateral recurrent mandibular dislocations, pain, and discomfort since the first event 9 years before surgery. The other patient had 1 single mandibular dislocation 2 years before surgery and suffered from unilateral pain and dysfunction after this event. In both patients, Annandale fixed the discs with catgut sutures. Both patients were dismissed from the hospital after 1 week with perfect and proper movements of the jaw. Konjetzny (1921) described a method of surgically reflecting the disc forward to create an obstacle for the condyle. Deepening of the glenoid fossa by resection of the disc was first described by Ashhurst in 1921. Dingman and Moorman followed in 1951.

Capsular Plication

Several methods of capsular plication and reinforcement of the joint capsule have been described; Rehn made the first report in 1919.

Tethering the Mandible

In 1918, Blake described a method of limiting mouth opening by fixing the coronoid process to the zygomatic arch by silver wires. Tethering the mandible with fascia slings from the mastoid fascia was presented by Link (1933). Scarification of the temporalis tendon (Maw and McKean, 1973) has a similar effect.

Blocking Procedures

Most procedures intended to prevent dislocation of the condyle try to create an obstacle in the path of the condyle: augmentation of the articular eminence with bone (Lindemann, 1925), anchoring procedures (Georgiade, 1965), downfracture of the zygomatic arch and its fixation medial to the tubercle (Leclerc and Girard, 1943; Gosserez and Dautrey, 1967), and the use of alloplastic implants to limit translation of the condyle (Aubry and Palfer-Sollier, 1956). Some of these methods are still used, but most are only of historical interest.

Lateral Pterygoid Myotomy

Another approach to the problem was presented by Boman in 1949: lateral pterygoid myotomy. With the introduction of botulinum toxin A, this method is also only of historical interest.

Condylectomy

Riedel (1890) and Myrhaug (1951) used deep condylectomy for the treatment of internal derangement, osteoarthritis, and recurrent dislocation. Anterior open bite was observed in bilateral cases, and facial asymmetry was observed in unilateral cases.

Condylotomy

The method of closed condylotomy, in which the condylar process is cut with the aid of a special Gigli saw, was first described by Kostecka (1934).

Arthroscopic Techniques

In 1991, Ohnishi presented a method of arthroscopic laser coagulation of the bilaminar zone with a neodym:yttrium-aluminum-garnet laser in combination with arthroscopic disc suturing. With arthroscopic vision, Merrill (1992) injected sclerotizing agents into the bilaminar zone, and Chossegros (1998) described arthroscopy-controlled coagulation of the retrodiscal tissue with the aid of a bipolar diathermy probe.

Arthroscopic eminoplasty, as described by Segami (1999), is presented in detail later.

Eminectomy

In 1951, Hilmar Myrhaug introduced eminectomy for the treatment of recurrent mandibular dislocation. Anthropologic research by Reisert revealed that the glenoid fossa and the articular tubercle were flat in historical dry skulls. Based on Reisert's work and his own observation that recurrent mandibular dislocation mainly occurred in patients with a deep overbite combined with a steep articular tubercle, Myrhaug proposed removing the articular eminence to allow the condyle to move freely. Many investigators have since described their experiences with the Myrhaug technique for the treatment of mandibular luxation: Irby 1953, Hale 1972, Goode and Linehan 1973, Westwood and colleagues 1975, Baumstark and colleagues 1977, Cherry and Frew 1977, Courtemanche and Son-Hing 1978, Van der Kwast 1978, Oatis and Baker 1984, Helman and colleagues 1984, Pogrel 1987, Reich and colleagues 1987, Sensoz and colleagues 1992, Undt and colleagues 1996 , Undt and colleagues 1997, Holmlund and colleagues 1999, Sato and colleagues 2003, Cardoso and colleagues 2005, Cascone and colleagues 2008, Güven 2009, Vasconcelos and colleagues 2009, Vasconcelos and Porto 2009, Klüppel and colleagues 2010, and Sainuiddin and colleagues 2010. Eminectomy in combination with redirectioning of the temporalis muscle was advocated by Ullik and Gay-Escoda.

Eminectomy: anatomic background

It is important for the surgeon to know the average dimensions of the articular eminence when performing surgical reduction of that structure (Fig. 3). Such knowledge helps avoid penetrating the infratemporal fossa or the middle cranial fossa. Hall and colleagues conducted an anatomic study on

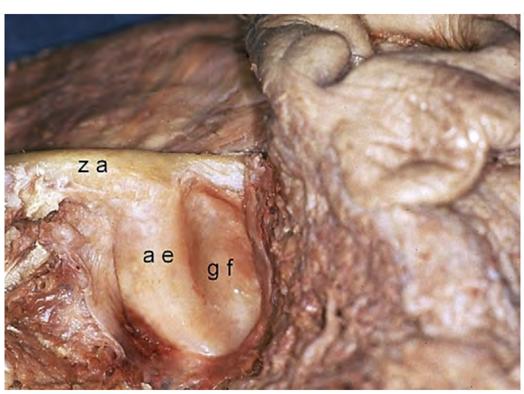

Fig. 3. Inferior view of the lateral skull base. The condyle, the disc, and the joint capsule have been removed. a e, articular eminence; g f, glenoid fossa; z a, zygomatic arch.

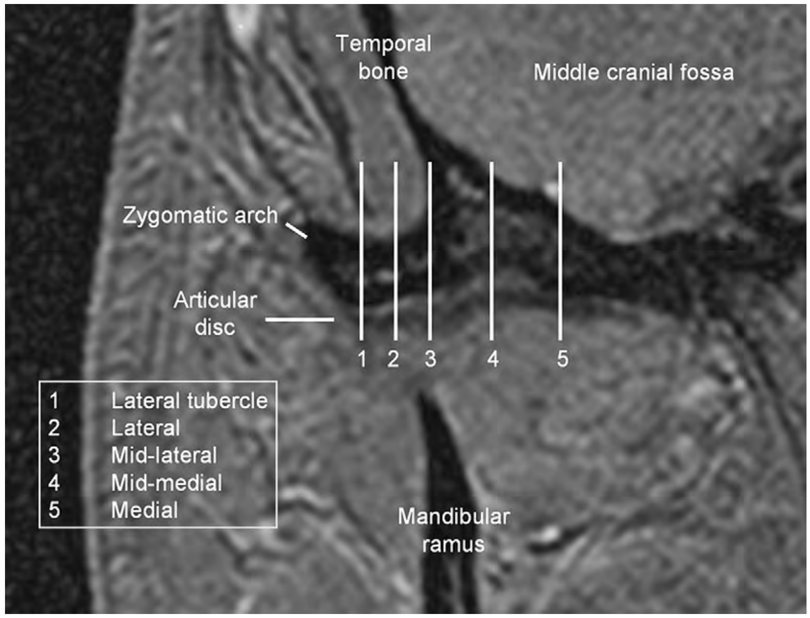

Fig. 4. Frontal section of a right articular eminence, visualized by a paracoronal MRI scan. The thickness of bone was measured in different sagittal slices. The results of the measurements are displayed in Table 1. (*Data from* Hall MB, Randall WB, Sclar AG. Anatomy of the TMJ articular eminence before and after surgical reduction. J Craniomand Pract 1984;2:135–40.)

38 cadaver half-heads to establish a guideline for eminectomy. They made the following measurements:

1. Length of eminence in anterior-posterior direction: $\bar{x} = 11$ mm, range = 9 to 18 mm
2. Length of eminence in lateral-medial direction: $\bar{x} = 21$ mm, range = 16 to 25 mm
3. Distance from the lateral tubercle to the temporal bone: $\bar{x} = 9$ mm, range = 5 to 14 mm

Comment: This distance is important because medial to the point where the temporal bone meets the eminence, penetration into the middle cranial fossa is a possible complication. Paracoronal magnetic resonance images are displayed in Fig. 4; computed tomography (CT) images are also useful to the surgeon to identify this point and to estimate the thickness of the eminence both laterally and medially.

4. Thickness of bone at the deepest portion of the fossa: $\bar{x} = 1.5$ mm, range = 0.1 to 8 mm

Comment: Especially when using arthroscopic techniques, there is a danger of entering the middle cranial fossa through the roof of the glenoid fossa with a needle or instrument. Parasagittal images of a preoperative magnetic resonance imaging (MRI) scan or CT scan allows the thickness of the bone at the deepest portion of the fossa to be estimated.

5. Thickness of the temporal bone superior to the eminence: $\bar{x} = 3.6$ mm, range = 1 to 7 mm
6. Thickness of bone of the eminence. Fig. 4 presents a frontal (paracoronal) section of the articular eminence recorded by MRI. The 5 vertical lines represent the thickness of bone that was measured laterally to medially. Each of these 5 measurements was taken at anterior, middle, and posterior sections of the eminence. Table 1 lists both the average value of bone thickness ($\bar{x}$) and the range of thickness.

Table 1
Bone thickness of the articular eminence in mm

	Lateral Tubercle	Lateral	Midlateral	Midmedial	Medial
Anterior (mm)	$\bar{x}$ = 7.9(6.5–12.0)	$\bar{x}$ = 3.2(1.0–5.1)	$\bar{x}$ = 4.9(2.7–7.0)	$\bar{x}$ = 9.7(5.0–15.0)	$\bar{x}$ = 6.0(3.6–12.0)
Middle (mm)	$\bar{x}$ = 9.5(6.6–11.0)	$\bar{x}$ = 4.9(2.5–6.5)	$\bar{x}$ = 6.3(2.8–9.1)	$\bar{x}$ = 10.3(3.5–14.0)	$\bar{x}$ = 6.2(3.5–14.0)
Posterior (mm)	$\bar{x}$ = 6.5(3.8–10.2)	$\bar{x}$ = 4.1(2.3–6.6)	$\bar{x}$ = 5.1(2.7–8.8)	$\bar{x}$ = 7.4(3.8–12.0)	$\bar{x}$ = 4.5(1.9–12.0)

Data from Hall MB, Randall WB, Sclar AG. Anatomy of the TMJ articular eminence before and after surgical reduction. J Craniomand Pract 1984;2:138.

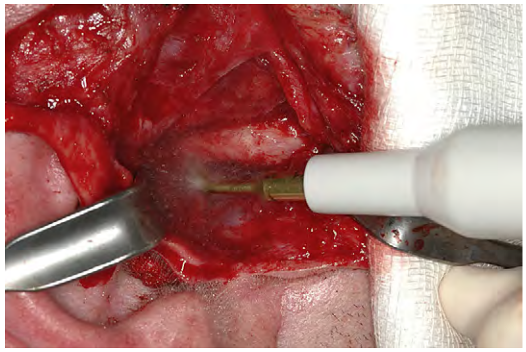

Fig. 5. Use of a piezo surgery device in TMJ surgery.

Eminectomy and eminoplasty: surgical techniques

After accessing the TMJ by one of the open approaches described in the literature, eminectomy is performed with the aid of chisels, rotating burs, or reciprocating bone rasps; a piezo surgery device might be used as well (Fig. 5). At the end of the procedure, the bony surfaces should be well rounded and smooth. After completing eminectomy, we recommend drilling holes into the lateral rim of the zygomatic arch and reinserting the joint capsule with resorbable sutures (Fig. 6).

The amount of bone that should be removed is still a subject of debate. Many investigators believe that the most medial parts of the eminence must be reduced in height to prevent recurrence, persisting pain, and the development of disc displacement following surgery. Goode and colleagues, Courtemanche and Son-Hing, Helman and colleagues, and Gay-Escoda recommend completely resecting the eminence (Fig. 7A), whereas other investigators recommend only reducing the height or partial contouring of the eminence (Hale, Baumstark and colleagues, Cherry and Frew, Van der Kwast, Reich, and Cascone and colleagues). Fig. 7B depicts the area of bone that should be removed according to our experience when performing open or arthroscopic eminoplasty.

An arthroscopic eminoplasty technique was described by Segami and colleagues in 1999: after insertion of the first arthroscopic portal into the posterior recess of the upper joint compartment by an inferolateral approach, diagnostic arthroscopy is undertaken to detect any intraarticular disorder, especially whether the eminence has an abnormal shape. Then, a second portal is inserted for the triangulation technique (Fig. 8). Next, an electric motorized shaver is inserted either through the second portal or through the first portal after having switched the arthroscope to the second portal (Fig. 9). In his original report, Segami enters the shaver through the first portal and reduces the eminence laterally to medially. The author of this article prefers to enter the shaver from the anterior portal. Both approaches

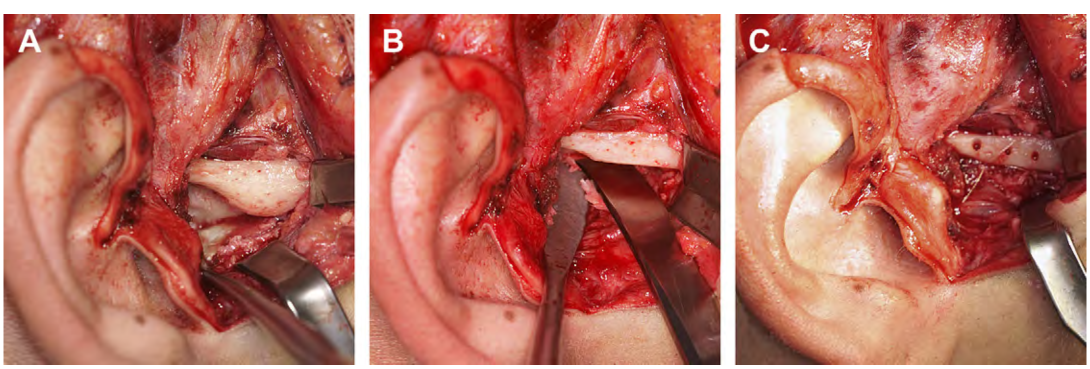

Fig. 6. (*A*) Preparation of the TMJ for total eminectomy. The joint capsule is carefully preserved when exposing the lateral parts of the eminence (articular tubercle). (*B*) Total eminectomy is performed with the aid of a chisel. All rough edges should be recontoured with a bur. (*C*) Following eminectomy, holes are drilled into the zygomatic arch and the joint capsule is reinserted.

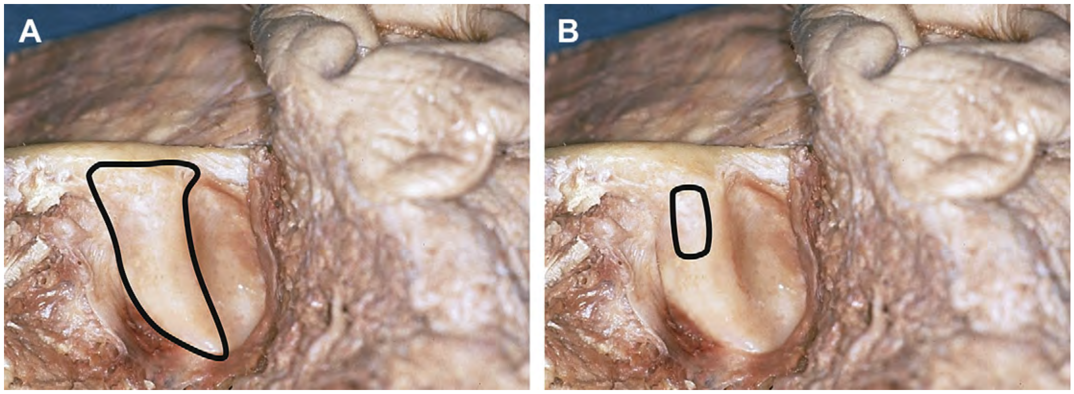

Fig. 7. (*A*) In this inferior view of the skull base, the margins for total eminectomy are outlined. (*B*) The outline shows the amount of bone to be removed, as recommended by the author. This partial eminectomy or eminoplasty encourages the formation of adhesions between the eminence and the disc, preventing further dislocations. The posterior slope of the eminence, as well as the medial portion, is left intact.

Fig. 8. Triangulation technique. A second portal is introduced into the anterior recess of the upper joint compartment allowing the use of surgical micro instruments.

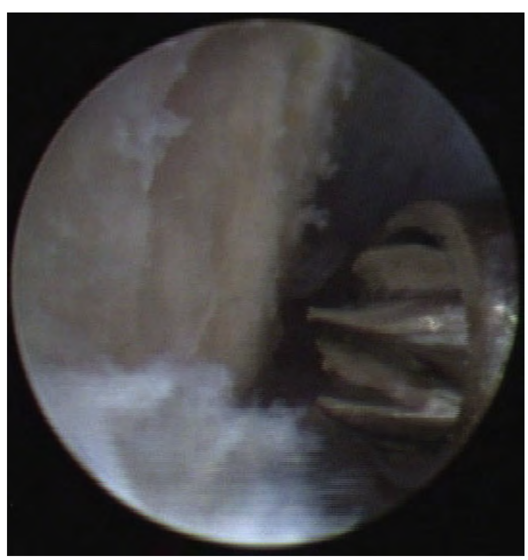

Fig. 9. A microbarrel abrader is used for shaping the eminence.

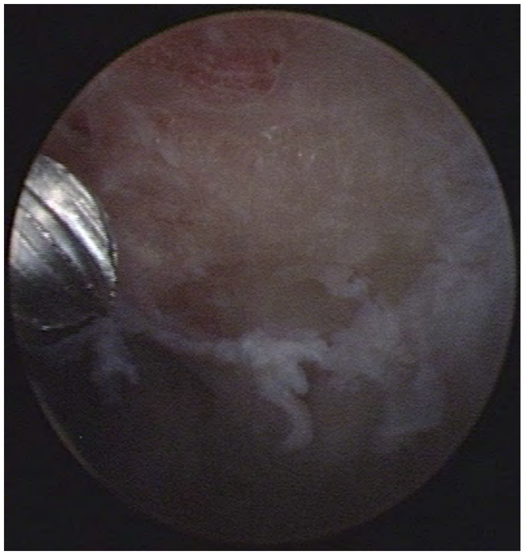

Fig. 10. Arthroscopic view of the area that has been shaved with the barrel abrader.

allow the height of the eminence to be reduced and the surface to be smoothed under direct vision (Fig. 10). The remaining debris is washed out by irrigation with saline solution.

We used a Stryker medical navigation system to visualize the position of the shaver tip in relation to three-dimensional CT data of the patient (Fig. 11). This navigation technique gives the surgeon information about the amount of bone that has been removed and helps to avoid areas of the eminence that lie directly under the middle cranial fossa. Based on our experience, it is enough to contour the lateral anterior parts of the eminence to prevent further dislocations (see Fig. 7B).

We advise the patients not to open their mouths beyond a maximum interincisal distance of 30 mm for 3 weeks after surgery to encourage the formation of adhesions. From the fourth week, the patient starts exercising under the supervision of a physiotherapist. These exercises start with mediotrusive and protrusive excursions of the mandible. In the following weeks, the interincisal distance is gradually increased to maximum excursions of 40 to 50 mm.

Unilateral or bilateral eminectomy?

Some investigators recommend eminectomy only as a bilateral procedure, whereas others also report unilateral cases. Recurrence was observed in unilateral as well as in bilateral cases.

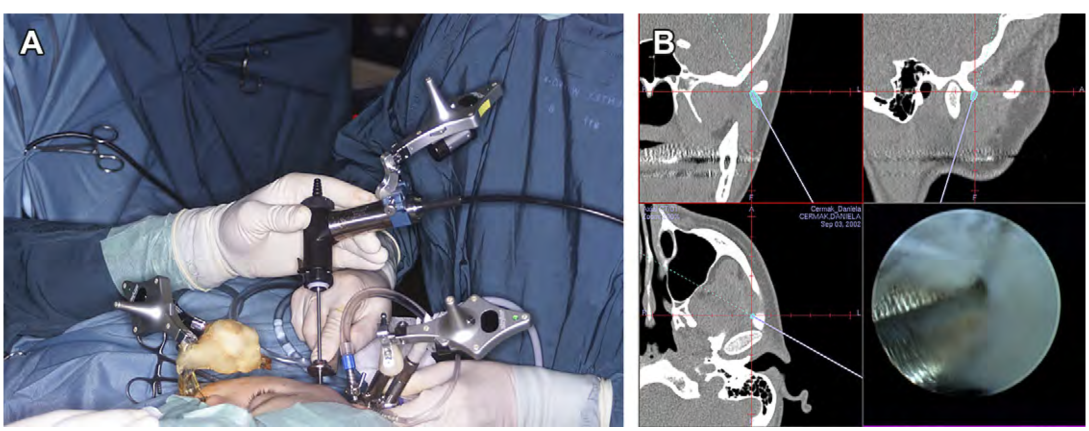

Fig. 11. (*A*) Navigation tools mounted to the head of the patient and to the surgical instruments transmit optical signals to the navigation system. (*B*) On the screen of the navigation system, the position of the tracked instrument (a shaver) is visualized in a coronal, a sagittal, and an axial plane. The fourth window displays the arthroscopic image.

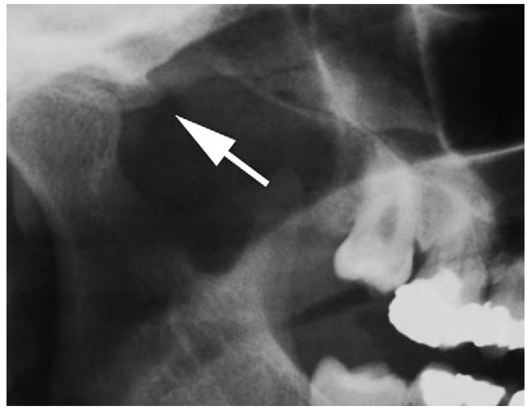

Fig. 12. Osteophyte (*arrow*) in the anterior aspect of the articular eminence 2 years after eminectomy in the right TMJ.

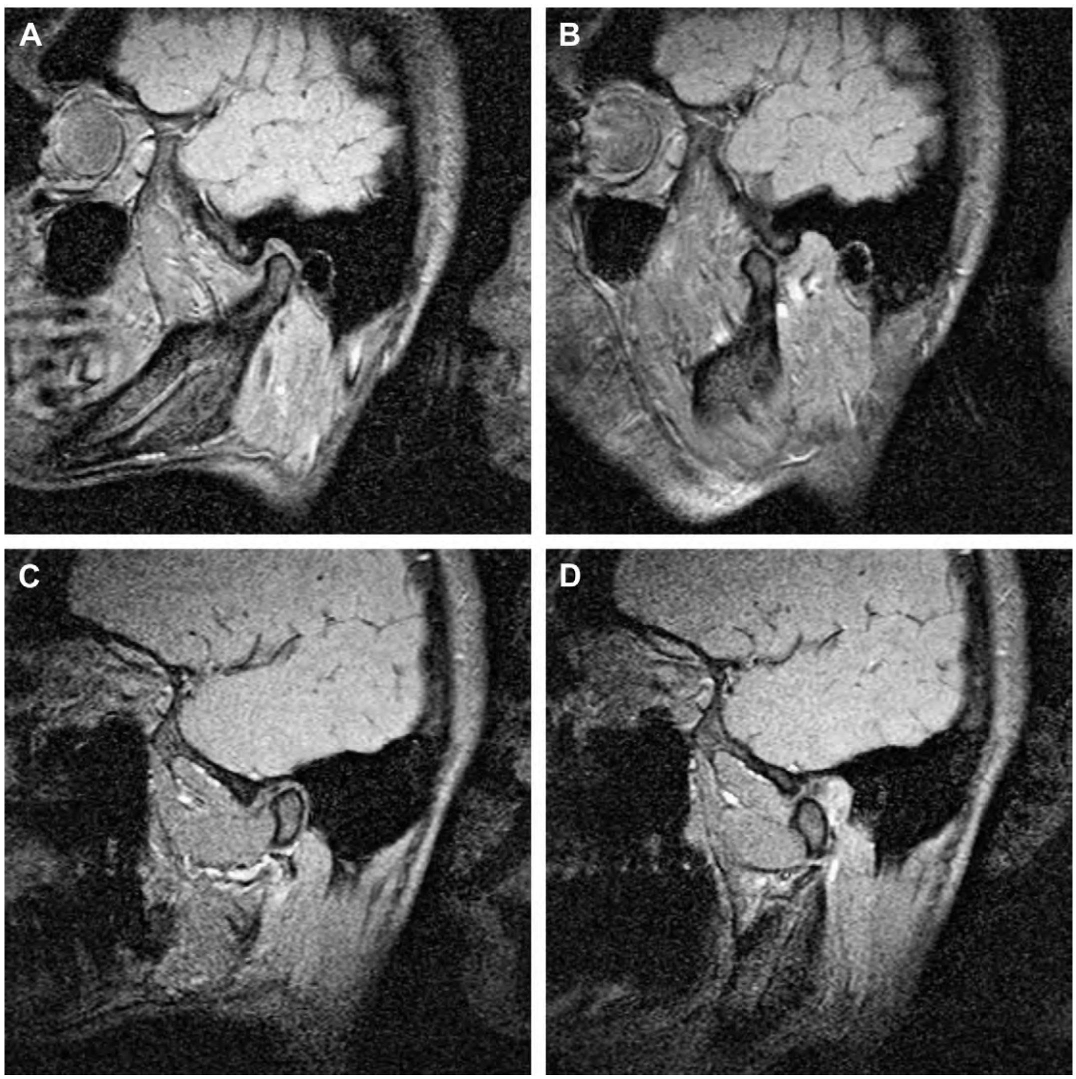

Fig. 13. (*A*) Parasagittal MRI scan of a left TMJ in the closed-mouth position before total eminectomy. (*B*) Parasagittal MRI scan of a left TMJ in the open-mouth position before total eminectomy. (*C*) Parasagittal MRI scan of a left TMJ in the closed-mouth position 18 months after total eminectomy. (*D*) Parasagittal MRI scan of a left TMJ in the open-mouth position 18 months after total eminectomy. The translation of the condyle is severely limited.

Fig. 14. Arthroscopic view of adhesions following partial open eminectomy.

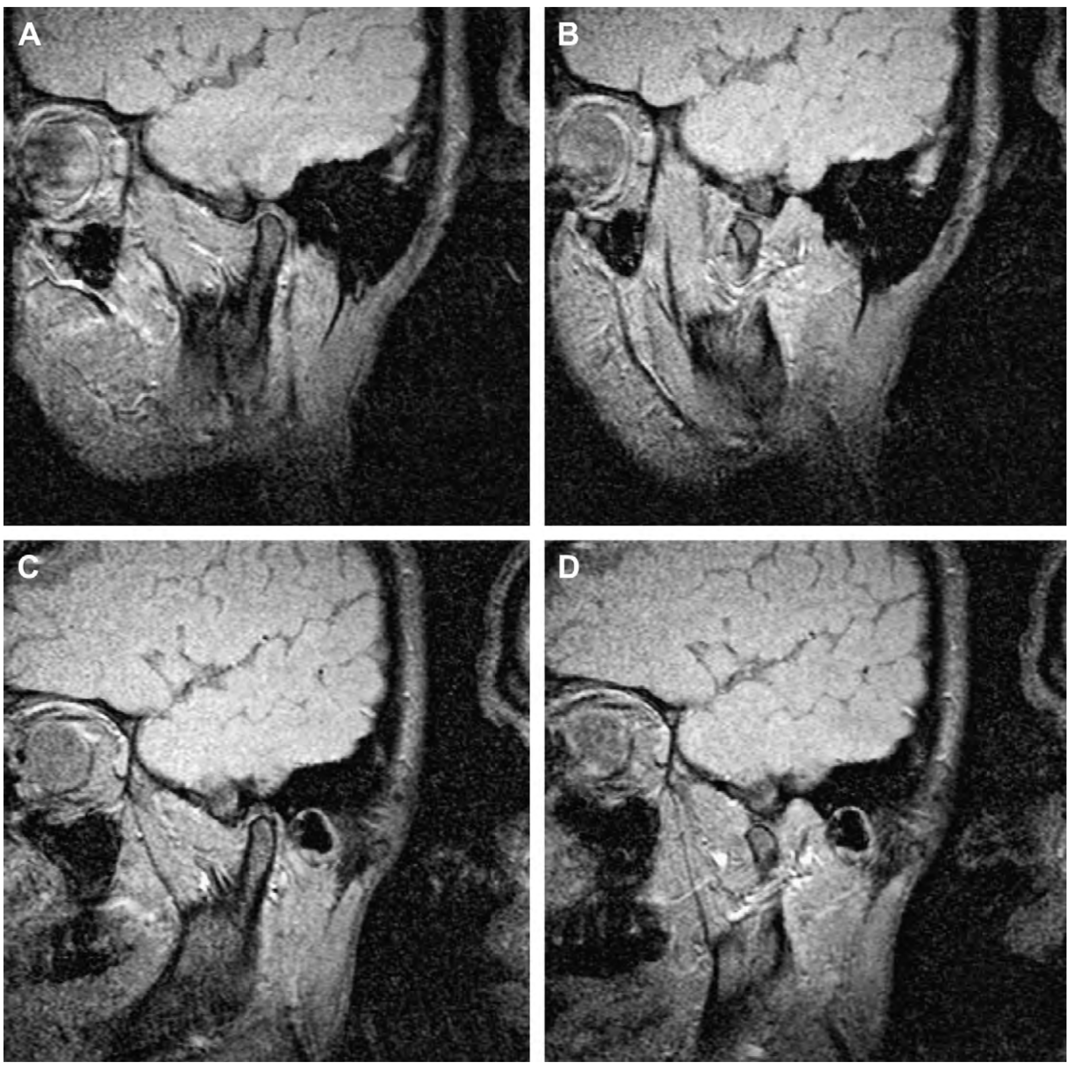

Fig. 15. (*A*) Parasagittal MRI scan of a left TMJ in the closed-mouth position before arthroscopic eminoplasty. (*B*) Parasagittal MRI scan of a left TMJ in the open-mouth position before arthroscopic eminoplasty. (*C*) Parasagittal MRI scan of a left TMJ in the closed-mouth position 12 months after arthroscopic eminoplasty. (*D*) Parasagittal MRI scan of a left TMJ in the open-mouth position 12 months after arthroscopic eminoplasty. The translation of the condyle is slightly limited.

Table 2
Maximal excursion of condyle in millimeters (n = 10 operated joints in 6 patients) **and maximal functional opening**

	Mean	Std dev	Min	Max	Sign
Protrusion					
Before surgery	11.2	3.6	7.1	19.0	
6 mo after surgery	8.4	1.6	5.9	11.2	$P < .05$
1 and 2 y after surgery	11.1	2.9	8.3	16.1	n.s.
Mediotrusion					
Before surgery	11.5	3.6	6.5	18.9	
6 mo after surgery	8.7	1.8	5.1	11.3	$P < .05$
1 and 2 y after surgery	11.9	2.9	8.8	16.9	n.s.
Opening					
Before surgery	14.1	2.8	8.5	18.8	
6 mo after surgery	8.2	4.0	1.9	14.2	$P < .001$
1 and 2 y after surgery	10.0	5.6	2.5	19.6	n.s.
Maximal Functional Opening					
Before surgery	44.7	5.5	32	52	
6 mo after surgery	45.4	7.9	30	58	$P < .001$
1 and 2 y after surgery	56.0	8.1	43	70	n.s.

Abbreviation: n.s., not significant.

From 1990 to 2002, 6 patients with unilateral recurrent mandibular dislocation (2 men and 4 women) underwent unilateral eminectomy for unilateral recurrent dislocation at the Hospital for Cranio-Maxillofacial and Oral Surgery, Medical University of Vienna, Austria. Five open eminectomies and 1 arthroscopic eminoplasty were performed. No recurrence has been observed. Although recurrence following unilateral eminectomy has been described in the literature, we recommend performing unilateral eminectomy in patients with unilateral recurrent dislocation.

Why is eminectomy effective?

Many investigators who have published on eminectomy and eminoplasty state that reducing the height of the articular eminence gives more freedom to the condyle. The procedure prevents the condylar head from locking in the infratemporal fossa and allows it to return easily into the glenoid fossa when the mouth closes. Some investigators report limited mouth opening following surgery. Having analyzed our series of 14 patients following open eminectomy, we came to the conclusion that formation of scars in and around the joint together with bone remodeling of the articular eminence (resorption and apposition of bone) might be the most important factors for the successful outcome of

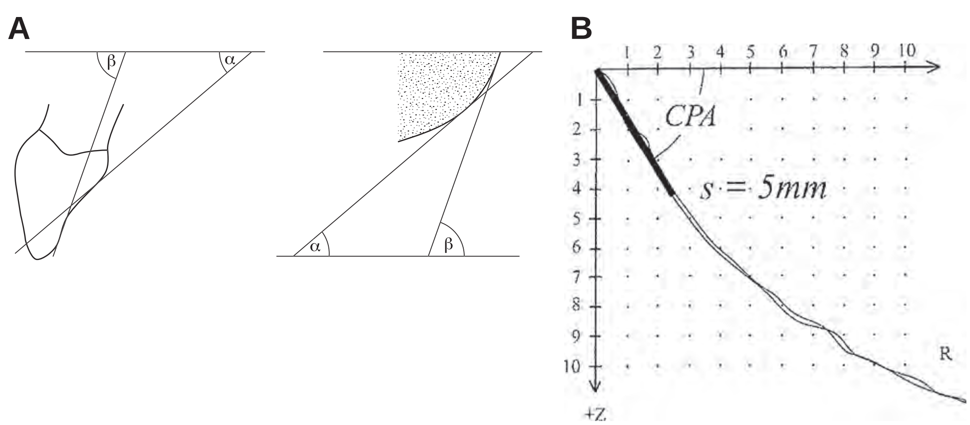

Fig. 16. (*A*) Relation between the inclination of the condylar path and incisal guidance. The initial flat frontal guidance angle alpha and the terminal steep frontal guidance angle beta correspond reciprocally to the protrusive condylar path angles. (*B*) Axiographic tracing of protrusive or mediotrusive movement in the right TMJ. The CPA is formed by a line tangential to the condylar path at an excursion of s = 5 mm from centric relation and the axis-orbital line. (*From* Undt G, Kermer C, Rasse M. Treatment of recurrent mandibular dislocation, part II: eminectomy. Int J Oral Maxillofac Surg 1997;26(2):100, 101.)

Table 3
Horizontal condylar inclination at s = 8 mm in protrusion in ° (n = 10 operated joints in 6 patients)

	Mean (°)	Std dev (°)	Min (°)	Max (°)	Sign
Before surgery	57.7	8.3	46	68	
1 and 2 y after surgery	54.3	10.9	39	68	n.s.

Abbreviation: n.s., not significant.

the procedure. Radiographic follow-up of our patients showed signs of active remodeling in the region of the eminence years after the eminectomy. Anterior osteophytes of variable size were observed in 10 of 23 joints (Fig. 12). In joints with the formation of pronounced osteophytes, the condyle showed limited translation in opening movements, whereas translation in protrusive and mediotrusive movements was not limited. The range of mouth opening was not limited in these patients. Thus, these patients developed a new mouth-opening pattern based on condylar rotation. MRI studies of these patients showed that adhesions had formed between the bone wound of the eminence and the disc, restricting translation of the condyle (Fig. 13). Arthroscopic inspection revealed the presence of massive adhesions, especially in the lateral and anterior upper joint compartment (Fig. 14). After arthroscopic partial eminoplasty, patients showed less adhesion formation as detected by MRI, and the range of translation in opening movements was almost unrestricted (Fig. 15).

Similar formation of adhesions was found by Hall and colleagues in their monkey experiments. The healing following meniscoplasty, eminectomy, and high condylectomy was studied in 5 *Macaca fascicularis* monkeys. After 5 months of healing, no discontinuity defects were found in any of the plicated menisci, and all recontoured bone surfaces had new soft tissue linings. Fibrous adhesions to the adjacent plicated meniscus developed in 2 of 4 joints on which eminectomy was performed. These adhesions formed between the disc and the surgically recontoured bone area but not between unrecontoured bony surfaces and the meniscus. Apposition or resorption of bone provoked by unloading or loading of the mandibular condyles in monkeys has been described by Ewers.

Eminectomy with or without concomitant disc plication has been advocated for the treatment of internal derangement of the TMJ. For this indication as well, formation of adhesions and scars as well as bone remodeling might be responsible for the positive effect of the surgery.

Joint function following eminectomy

Does eminectomy limit the translation of the condyle? It seems that it temporarily does. In our investigation, 6 of the 14 patients had significantly limited maximal range of excursion of the condyle

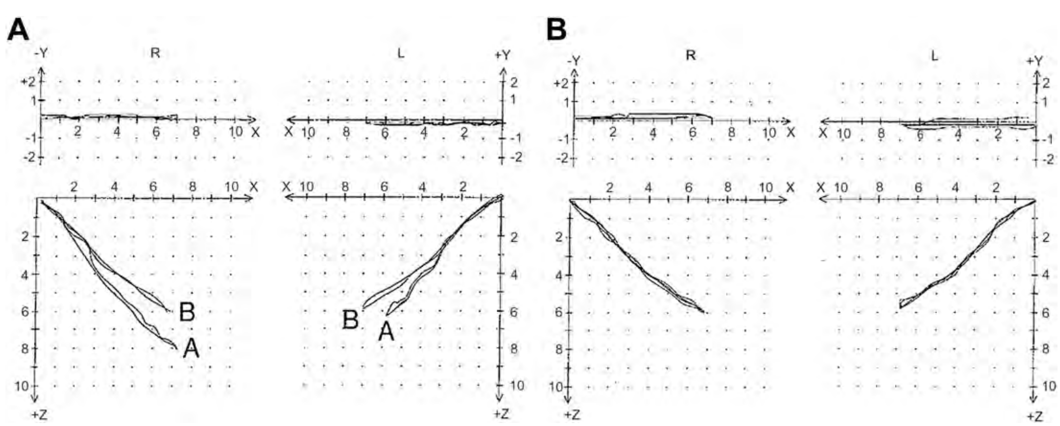

Fig. 17. (*A*) Superimposition of protrusive/retrusive movements recorded preoperatively (A) and 18 months after bilateral eminectomy (B), showing a slight decrease in the CPA. (*B*) Superimposition of unguided protrusive/retrusive movements and the same movements under manual cranial compressions in both joints. These tracings, recorded 18 months after bilateral eminectomy, suggest bony guidance in translatory movements. (*From* Undt G, Kermer C, Rasse M. Treatment of recurrent mandibular dislocation, Part II: Eminectomy. Int J Oral Maxillofac Surg 1997;26(2):100.)

Table 4
Results following open eminectomy (see Further Readings)

Author	No. of Patients	Recurrence
Baumstark et al 1977	8	0
Cherry and Frew 1977	8	2
Oatis and Baker 1984	15	1
Pogrel 1987	15	0
Undt et al 1997b	14	1
Sato et al 2003	11	3
Vasconcelos and Porto 2009	10	0

compared with the preoperative excursion 6 months after surgery based on computer-aided axiography. The range of excursion returned to preoperative values within 1 to 2 years. Although the maximum range of condylar excursion in protrusive, mediotrusive, and opening movements returned to the preoperative values, the maximum interincisal distance of the patients significantly exceeded the preoperatively measured values 1 and 2 years after surgery (Table 2A-D). Thus, after an initial phase of limitation, the patients regained their full range of mouth opening without any further dislocations.

A close relationship exists between the inclination of the condylar path and the incisal guidance, which, according to prosthodontists, should not be deranged (Fig. 16A). If reduction of the height of the articular eminence results in a decrease in the steepness of the posterior slope of the eminence, then an imbalance between this angle and the incisal guidance should be observed. Comparing the horizontal condylar path inclination at an excursion of $s = 5$ mm from centric relation (condylar path angle [CPA]) in protrusive and mediotrusive movements (see Fig. 16B) in preoperative and post-operative axiographic tracings of 6 patients, we found only a slight decrease in the CPA (Table 3). Using a paired *t*-test, the difference did not prove to be significant. Superimposition of axiographic tracings from the same patient before surgery and 6 months after surgery did not show any major changes in the condylar path (Fig. 17A). With cranial compression in the operated joint, the condylar path remained exactly the same (see Fig. 17B), which means that the curve reflects the bony contour of the eminence and not the muscle-guided movements of the condyle. Eminectomy and subsequent bone remodeling only caused a slight decrease in the steepness of the posterior slope of the eminence.

Clinical results following eminectomy for recurrent mandibular dislocation

The rate of recurrence after eminectomy for recurrent mandibular dislocation is shown in Table 4. Only papers that report more than 8 patients are included. Table 5 gives an overview of the results following arthroscopic eminoplasty; the author's own cases (11 joints in 6 patients) are reported as well.

Although several papers report joint noises and pain after eminectomy, 2 studies give detailed reports about the quality and intensity of joint noises and pain before surgery and at the time of recall.

In our study from 1997, from 1990 to 1995, 14 patients (6 men and 8 women) underwent unilateral (5) or bilateral (9) eminectomy for recurrent mandibular dislocation (see Table 1). Age at the time of surgery ranged from 19 to 84 years (mean 36.9 years). The first acute dislocation had taken place 4 months to 10 years before surgery, with an average of 32 months. The incidence of repeated mandibular dislocations without spontaneous reduction varied between 7 luxations in 10 years to 6 luxations daily for 1 year. The postoperative follow-up period ranged from 7 months to 5 years (mean 2.3 years).

Table 5
Results following arthroscopic arthroplasty (see Further Readings)

Author	No. of Patients	Joints	Recurrence
Segami et al 1999	11	16	1 joint
Sato et al 2003	8	24	6 joints

Table 6
Eminectomy: clinical follow-up

Patient		Age (y)	Sex	Previous Operative Treatment	Date of Eminectomy	Side	Before Surgery (Right/Left)			After Surgery (Right/Left)			Follow-up
							Pain	Clicking	Crepitus	Pain	Clicking	Crepitus	
1	MM	26	M	Dautrey blocking procedure 2/90	5/90	Bilateral						+/+	Fracture of left condylar head 1/93
2	FS	65	F	Dautrey blocking procedure 11/89	7/90	Bilateral	2	+/+		2	+/+	+/+	
3	HW	26	M		12/90	Left					/+		
4	HB	39	M		5/91	Left	1	/+			/+		
5	MR	20	F		4/92	Bilateral	1	+/+				+/	single non self- reducing condylar luxation 11/94
6	FW	66	F		10/92	Bilateral[a]			/+			/+	
7	JF	33	M		3/93	Bilateral	1		+/	1		/+	
8	MW	19	M		5/93	Right	1			1	+/	+/	osteoarthrosis of right TMJ
9	DS	26	F	Dautrey blocking procedure 2/93	12/93	Left	2	/+		1	/+	/+	
10	MK	84	F		12/93	Bilateral							
11	MN	31	F		2/94	Right	1	+/				+/	
12	IH	31	f		3/94	Bilateral					/+		
13	MB	24	f		12/94	Bilateral	1						
14	HK	26	M		4/95	Bilateral	1	/+					

Grading of pain: 1, mild; 2, moderate; 3, severe.
[a] Together with repair of disc perforation on left side.

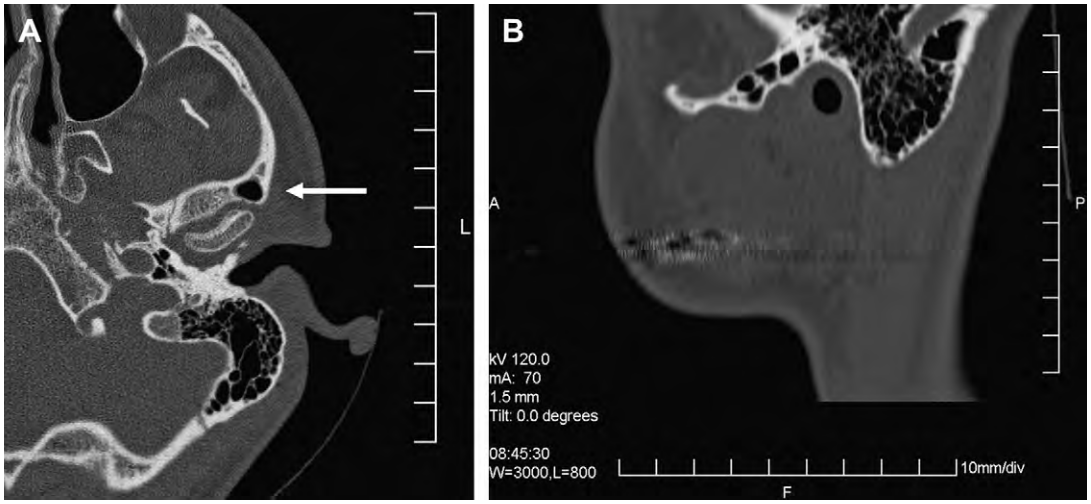

Fig. 18. (*A*) Pneumatization (*arrow*) of the articular eminence. (*B*) The air cells in the eminence have a connection to the mastoid air cells.

Included in the group of 14 patients were 3 patients with recurrence after Dautrey's operation. Among the 14 patients, there were 8 with a history of neurologic disorders (grand mal epilepsy, Parkinson disease, hemiparesis after cerebral apoplexy) or with psychiatric diseases treated with neuroleptic medication. The clinical results are displayed in Table 6.

Possible complications of eminectomy and arthroscopic arthroplasty

All the possible complications reported in connection with the open and arthroscopic approaches to the TMJ should be considered when performing open or arthroscopic eminoplasty. Lesions of the facial and trigeminal nerves as well as damage to other adjacent structures (middle ear, middle cranial fossa, branches of the external carotid artery) must be taken into account.

Pneumatization of the zygomatic arch and the eminence is rare (Fig. 18A, B). Yavuz and colleagues found air cells in this location in 83 of 8107 patients (42 male and 41 female patients, total incidence 1.03%). The disorder should be recognized before indicating eminoplasty or eminectomy to avoid intraoperative perforation of the cells. Kulikowski and colleagues reported a case of unilateral pneumatized temporal bone eminence that was perforated with a chisel during eminectomy. They repaired the defect by repositioning the bone and fixing it with a steel wire.

Summary

1. Eminectomy and eminoplasty performed in recurrent mandibular dislocation are well-established treatment modalities with a good success rate and low morbidity. However, all possibilities of conservative management of the disorder should be exhausted before indicating surgery.
2. Coronal MRI or CT scans should be obtained before surgery to inform the surgeon about the bone thickness to be expected in different parts of the eminence. Careful imaging diagnosis allows detection of pneumatization of the eminence; if air cells exist in the area, eminectomy and eminoplasty should not be performed.
3. The successful outcome following eminectomy is because of the formation of scars and adhesions in and around the joint, as well as bone remodeling in the area of the reduced eminence.
4. Within the first 3 weeks following surgery, the patients should not open their mouths wide to encourage the formation of adhesions. From the fourth week on, the patient should start exercising under the supervision of a physiotherapist.

5. Total eminectomy does not seem to be necessary. Removing (lateral) parts of the eminence by open or arthroscopic eminoplasty allows adhesions to form between the disk and the eminence.
6. In unilateral recurrent dislocation, we recommend performing unilateral eminoplasty.

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Atlas of the Oral and Maxillofacial Surgery Clinics

Resection of the Severely Ankylosed Temporomandibular Joint

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Few deformities of the maxillofacial region present with such a wide constellation of symptoms and clinical findings as ankylosis of the temporomandibular joint. Pain, swelling, disruption of diet and speech, airway complications, and the creation of cosmetic deformities all can result from this severe defect of the mandibular zygomatic complex. The basic surgical goals for correction of this deformity are threefold: to free up the ankylosis, to return the patient to function, and to prevent recurrence. The last 2 of these 3 goals are usually dependent on placement of an interpositional barrier following release of the fibrous or bony fusion that can be either prosthetic or tissue borne.

The most common causes of severe ankylosis of the temporomandibular joint are posttraumatic, but arthritis, infection, and scar tissue from previous surgery all are known etiologic factors. The 3 subtypes of ankyloses are classified depending on the extent of involvement: stage1, bony ankylosis limited to the condylar process; stage 2, ankylosis of bone reaching the sigmoid notch; and stage 3, ankylosis involving the coronoid process.

In the past, the surgical treatment of this problem has been regarded, even by the most experienced surgeons of our profession, as an undertaking that is fraught with complications such as bleeding and nerve damage, which can produce much anxiety for the surgeon with the possibility of potential morbidity for the patient. A portion of this anxiety is well founded in that the surgeon is operating in an area generously populated with major vessels that are difficult to access for control and blanketed by the 5 branches of the facial nerve where slight damage to any one of them could cause a significant cosmetic facial deformity.

The purpose of this article is to present a step-by-step approach to the correction of this deformity. While each deformity is different and may present a different set of anatomic findings, the theoretical approach remains the same: to always be in a position to deal with complications if they arise by having good visibility and access to the surgical field, through a careful and systematic approach.

Anesthesia considerations

While the airway is always the most essential factor in a successful anesthetic, it becomes more problematic in a patient with a limited opening due to an ankylosis deformity. The anesthesia team must be made aware that the mandible will be unable to be mobilized even with adequate muscle relaxation. Fiberoptic intubation or tracheostomy becomes the usual option to secure an adequate airway for this relatively prolonged procedure. All options need to be discussed and accepted by the patient, and adequate preparation for a surgical airway need to be in place in the event the endotracheal intubation is unsuccessful.

Hypotensive anesthesia is highly recommended for this procedure. The institution of an arterial line will allow the anesthesia team to safely maintain a mean arterial pressure in the range of 55 to 60 mm Hg and can be adjusted depending on the comfort of the anesthesia team relative to the

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medical condition of the patient. This technique is helpful in maintaining a dry surgical field, restricting blood loss in the event of a bleeding episode, and obtaining serial blood labs if necessary.

As with any procedure involving transcutaneous approaches to this area of the facial skeleton, the anesthesia team needs to know that the use of long-acting muscle relaxants is to be avoided until access to the mandible has been completed, to facilitate identification of the facial nerve branches.

Technique

Once the patient is intubated, before positioning, prepping, and draping, any intraoral procedure is completed such as placement of arch bars or fixation screws. The patient is then positioned with turning of the head or the table to provide maximum comfort and access for the operator followed by prepping and draping of the surgical field.

The skin incision for this procedure is similar to most involving the temporomandibular joint, through a preauricular approach. The usual precautions for protecting all branches of the facial nerve are taken but because of the wide exposure needed for this procedure and the use of anterior retraction, some temporary partial nerve trauma can almost always be anticipated. In an effort to avoid this complication some surgeons modify the initial incision by taking it down to temporal bone and bring the complete musculocutaneous flap forward. This technique is not always necessary, but does allow excellent exposure while protecting the facial nerve.

The first bony landmark to be identified is the zygomatic arch. Even in the most severe cases the arch can be identified as the most superior extent of the deformity. Subperiosteal dissection is then taken forward along the arch to identify the extent of the deformity. With obliteration of the joint space in the ankylotic joint, the next reliable bony landmark is the neck of the condyle. Once the neck is identified, subperiosteal dissection is taken down from the zygomatic arch to what can be identified as the posterior border of the neck or ramus of the residual defect. Once this is identified, the first Dunn retractor (Fig. 1) is placed carefully around the back of the posterior border. Subperiosteal dissection now continues anteriorly to identify the anterior border of the deformity, which is usually the neck of the residual condyle. When this is identified, the second Dunn retractor is carefully placed in a subperiosteal position around to the medial surface of the neck (Fig. 2). If the ankylosis only involves the condyle, these retractors are now ready to provide the operator with excellent exposure of the deformity and protection of the soft tissue anterior, posterior, and medially from any high-speed instruments used to incise the deformity. If the deformity is large and obliterates the entire sigmoid notch, further dissection needs to be taken along the zygomatic arch and medially to the anterior border of the ascending ramus. The Dunn retractor can then be placed around to the medial surface to expose the entire bony fusion before attempting the initial bone incision (Fig. 3).

The goal of the first bone incision is to break the bony fusion at any level that is well exposed, protected by retractors, and requires a minimal amount of medial cutting; this is usually lower on the

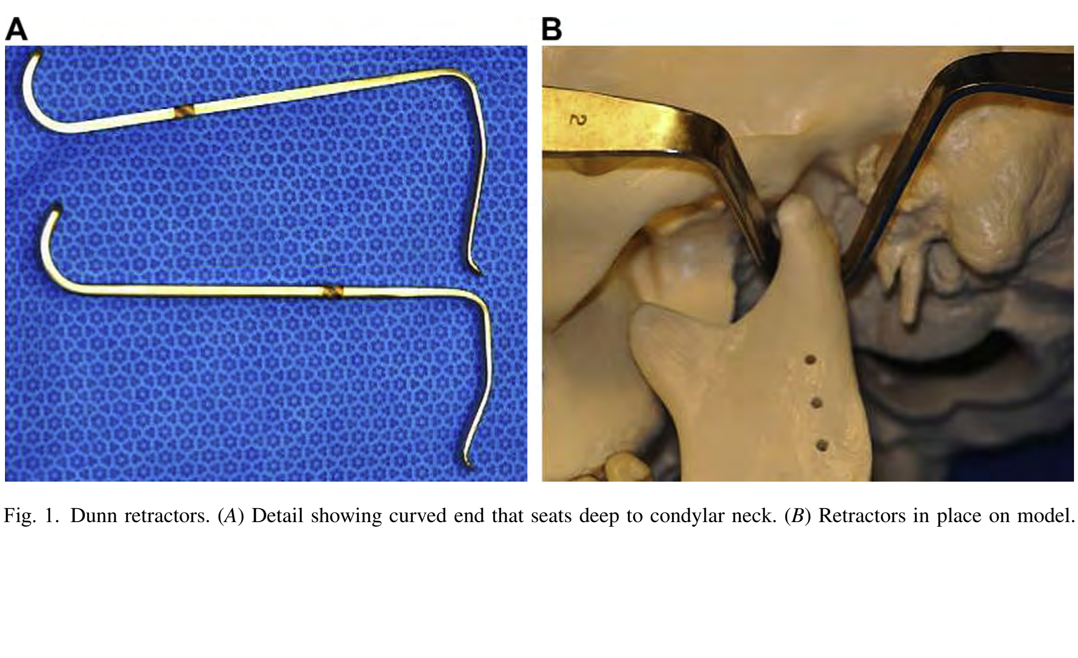

Fig. 1. Dunn retractors. (*A*) Detail showing curved end that seats deep to condylar neck. (*B*) Retractors in place on model.

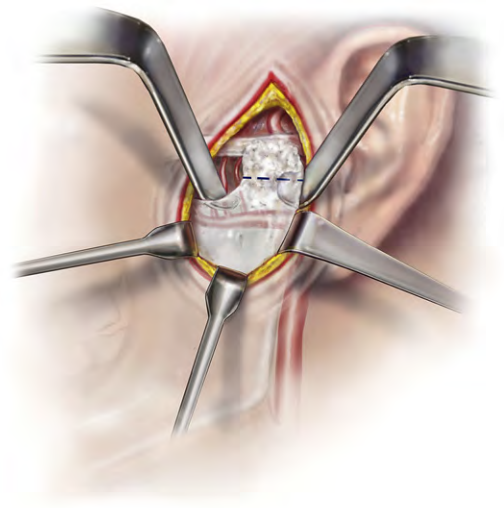

Fig. 2. Dunn retractors in place. Dashed line shows initial bone incision. (*Courtesy of* David J. Dattilo, DDS, Pittsburgh, PA.)

neck inferior to any medial bony deformities that may be a result of a previously fractured condyle. Initial testing of the completeness of the osteotomy can be tested with a small osteotome or a bone spreader. Once it is established that the osteotomy is complete, additional bone can be removed from the inferior or ramus side of the cut because this side has the more predictable anatomy. A reciprocating rasp, a small burr, or an oscillating saw can be used to create a larger gap between the two cut edges. Better access to the ramus for further bone removal can be obtained by having an assistant push up on the angle of the mandible, bringing the ramus stump into the already established gap (Fig. 4).

Creating this initial gap between the two segments accomplishes two goals: providing direct access to the vital structures medial to the deformity, and establishing direct visualization and access to the sometimes malformed and medially displaced superior bony deformity. Now with judicious subperiosteal dissection, the bony deformity can be identified and removed with a reciprocating rasp and hand instruments (Fig. 5). If any bleeding should occur, direct pressure as well as cautery can be applied with reasonable visualization.

At this point, the operator's main objective is to continue to widen the gap between the two cut surfaces in preparation for whichever interpositional replacement, if any, is chosen. In most cases of severe ankylosis the operator chooses to remove the coronoid process with its temporalis attachment to assist in reestablishing a better opening capacity of the mandible. This goal is accomplished by extending the bony incision anteriorly along the base of the process to the ascending ramus. While

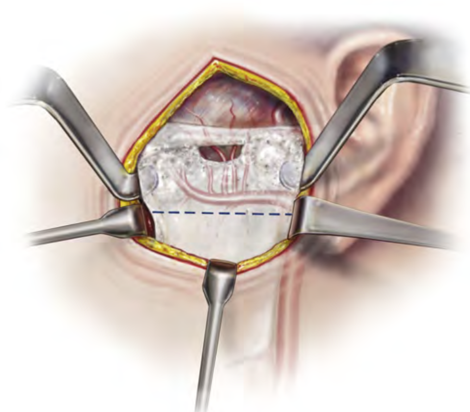

Fig. 3. Extended exposure with Dunn retractor placed anterior to coronoid process for large ankylotic bone mass. (*Courtesy of* David J. Dattilo, DDS, Pittsburgh, PA.)

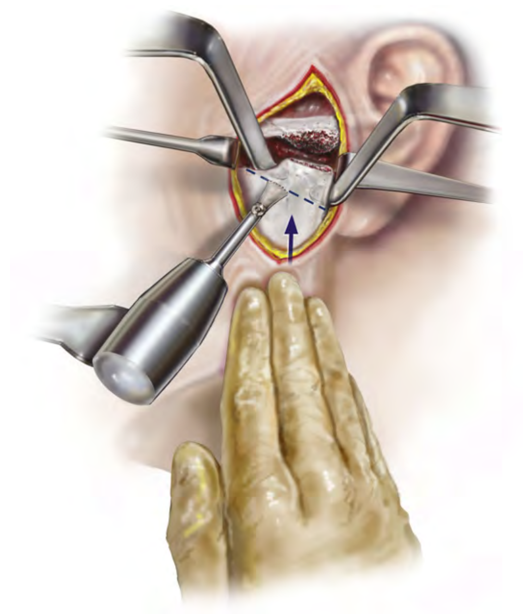

Fig. 4. After initial osteotomy is performed additional bone is exposed for resection by pushing up from the angle of the mandible. (*Courtesy of* David J. Dattilo, DDS, Pittsburgh, PA.)

clamping the cut base of the process in one hand, the operator can now strip the muscle attachment from all surfaces until the bone segment is completely free for removal.

If immediate replacement with either an autogenous or a prosthetic implant is anticipated, access to the ramus through a submandibular incision will be necessary. Performed early on in the procedure, this access can help in several ways in providing additional access to the ankylosed deformity. Stripping of the pterygomasseteric sling will help mobilize the mandible; clamping of the angle and moving the posterior ramus into the superior gap can improve access to further bone removal, and in some cases access for the coronoidectomy is better achieved through this approach.

If a staged procedure or simply a gap arthroplasty is planned, tissue grafts or sialastic spacers can be placed at this point, and the wound is closed. If immediate reconstruction with a prosthetic implant is planned, preparation of the fossa bed can be done through the superior incision followed by placement of the prosthesis. The patient is then put into intermaxillary fixation establishing the desired occlusion and vertical dimension. Through the lower incision the ramus can be prepared and the condylar prosthesis or autogenous graft can be placed.

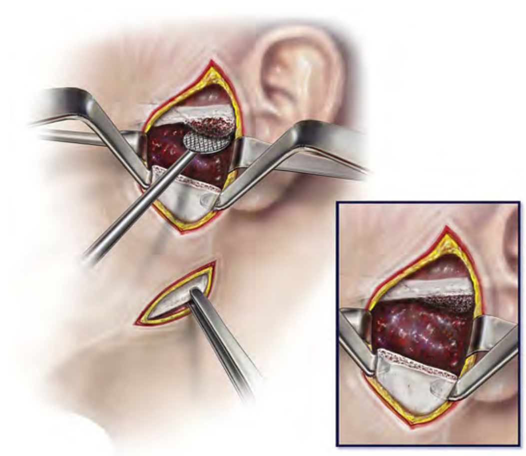

Fig. 5. The angle of the mandible can be exposed and pulled inferiorly, improving access to deeper bone on the ramus or temporal area. (*Courtesy of* David J. Dattilo, DDS, Pittsburgh, PA.)

In most cases, access to the oral cavity is necessary to either mobilize the mandible or to establish an occlusion with intermaxillary fixation for a short period of time. Careful attention needs to be paid to maintaining separate fields of surgery to prevent cross-contamination of bacteria from the unsterile oral cavity to the main surgical site. Separate “clean” and “dirty” instrument trays need to be designated, and members of the operating team must change gloves and sometimes gowns when transitioning between the two fields.

Postoperatively, in cases of gap arthroplasty and prosthetic total joint replacement, immediate physical therapy is the rule. For the first week, while the surgical wounds are healing and postoperative pain is still a factor, the patient can undertake passive therapy to a point of their own personal tolerance, which can be followed by a more regimented program of mechanical therapy provided by devices such as the Therabite Jaw Rehabilitation System (CranioMandibular Rehab, Denver, CO, USA). This aggressive therapy has been shown to be very important in preventing reoccurrence of the ankylosis and providing the best possible function of whichever interpositional implants are placed. In a staged procedure, when a postoperative computed tomography scan is needed for fabrication of a custom joint replacement, maxillomandibular fixation may be necessary for a short period of time. Also, in children and young adults receiving replacement rib grafts, it is recommended that the patient be kept in maxillomandibular fixation for 10 days followed by an aggressive program of jaw physiotherapy.

Immediately following surgery and during the initial jaw physiotherapy sessions, the patient may need intense pain control therapy. Oral pain control, however, should be tapered to nonsteroidal anti-inflammatory medication as soon as possible. In some cases of long-term facial pain arising from a variety of factors prior to surgery, it is best to have a pain specialist on board as part of the treatment team to help deal with pain issues immediately following the surgery and for the longer term if necessary.

During the initial jaw-opening therapy no other oral procedures should be performed other than routine hygiene and necessary caries control. Permanent reconstructive efforts such as dental implants, crown and bridge, and removable prosthodontics should be held off for at least 3 months until it is assured that the arch relationship and vertical dimension are stable. The use of prosthetic replacements will allow earlier intervention, due to the lack of remodeling and resorption in the reconstructed area.

Bleeding

One of the many caveats to Murphy’s law “if you have too much of it you will probably never need it” applies to the presurgical preparation for treating unforeseen bleeding complications. Even the most careful and experienced surgeon will at times be faced with bleeding in areas where there is very limited accessibility. As alluded to in the introduction, vessels under high pressure medial to the surgical site such as the maxillary and meningeal arteries can at times become injured with a minimum of trauma. Following initial pressure on the surgical site with packing and manipulation of the systemic blood pressure to stem the flow, the surgeon must find a way to either directly or indirectly stop the bleeding.

Direct measures for controlling bleeding in the surgical field are without doubt the most desirable. Electrocautery for the deeper tissues should be limited to bipolar, so that the area that the energy is delivered to is limited and there is a less chance of collateral injury to surrounding vital tissues. There are certainly times, however, when conventional cautery is either not enough for a high-pressure bleed or may damage vital structures in a very sensitive area. In these cases topical application of coagulation products that depend on platelet activation and clot formation such as topical thrombin, oxidized cellulose (Surgicel; Ethicon, Somerville, NJ, USA), or microfibrillar collagen (Avitene; Davol, Warwick, RI, USA) are necessary.

In recent years new combinations of these products have been developed to deal with bleeding in areas difficult to access. Flo-Seal (Baxter International, Deerfield, IL, USA) is an example of one of these products. This product depends on the combination of two active ingredients, gelatin granules and thrombin. When injected into an active bleeding site and then covered with a packing, the gelatin granules will expand to 20% of their original size, blocking the walls of the injured vessels. The residual blood that percolates through this barrier will then encounter the thrombin, which will facilitate the production of fibrin and help form a stable clot. This effectively produces a topical embolization of the injured vessel that in some cases is not even visualized. The high success of these newer materials has taken some of the anxiety out of performing this type of surgery.

In the past the most common indirect approach to the problem of bleeding that is difficult to control has been the ligation of the external carotid artery. In certain cases where multiple surgical procedures have been performed and scarring has made most of the anatomic structures medial to the deformity unpredictable, some surgeons find it prudent to begin the approach to the carotid area by performing a retromandibular incision (that can also be used for ramus reconstruction) before beginning any of the cuts to relieve the ankylosis deformity. Through this incision the ramus of the mandible as well as the external carotid artery can be accessed if necessary. Studies have shown that ligation of the external carotid artery anywhere from the bifurcation to the facial artery can be essentially ineffective, as it reduces the blood flow to the maxillary artery by less than 40%. Because of the widespread collateralization of blood flow in this region, effective reduction of blood flow can only be accomplished with ligation above the level of the facial artery. At this level, reduction of maxillary blood flow can be expected in the range of 70% to 90%. Anatomically, this would be just above the superior border of the stylohyoid muscle (Fig. 6).

Another indirect approach is fluoroscopic embolization, which is usually reserved for the most serious cases that are not responsive to other surgical measures. It requires that a facility have the appropriate equipment and trained invasive radiology staff immediately available to carry out this rather sophisticated procedure.

Reconstruction

As mentioned in the opening paragraphs, the success of treating ankylosis of the temporomandibular joint is just as dependent on the final interpositional replacement as it is on the performance of

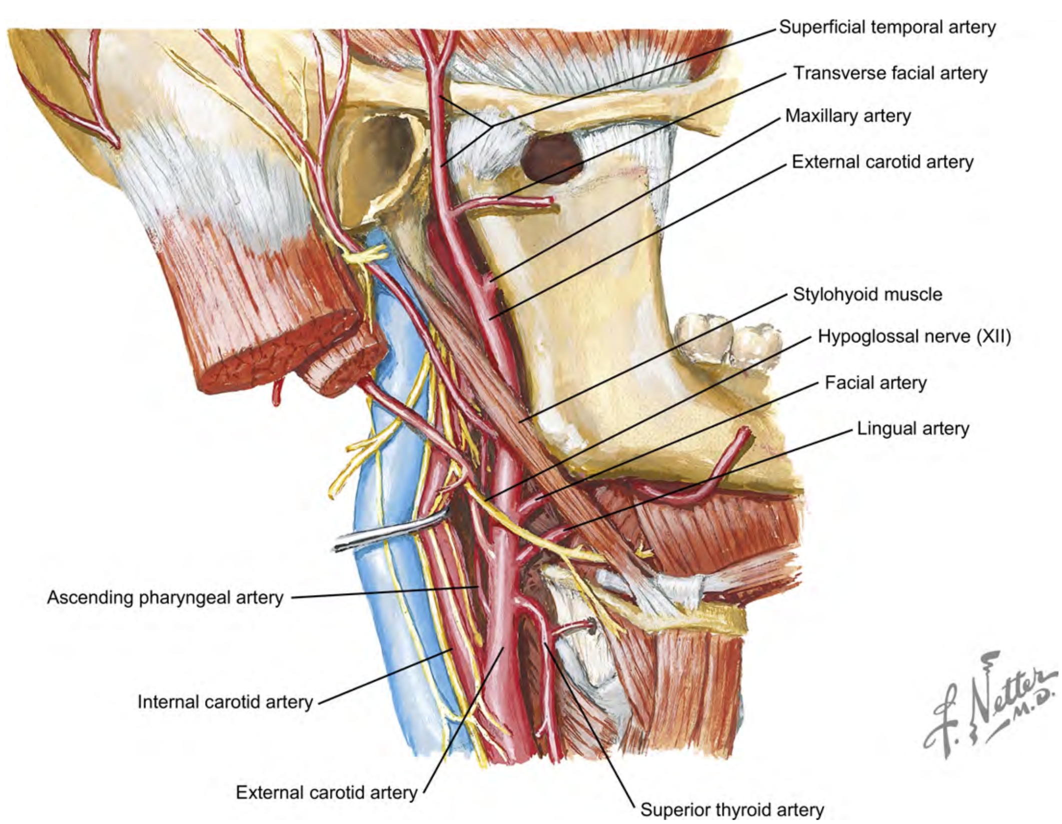

Fig. 6. Branches of the external carotid artery. If ligation of the external artery is necessary to control bleeding, the branches must be identified and the artery ligated above the facial artery. (Netter illustration *from* www.netterimages.com. Copyright Elsevier Inc. All rights reserved; with permission.)

a meticulous removal of the deformity. Much controversy has arisen over the use of autogenous tissues versus prosthetic components for the final replacement that will best return these damaged joints to function.

Free rib grafts remain the treatment of choice for children and adolescents. The ability of these grafts to continue to contribute to growth, maintain function, and provide excellent bone stock for any future reconstructive procedure make them the implant of choice in the younger age groups. Rib grafts in the adult population have not been as successful. Erosion of the articulating end of the graft by inflammation with the subsequent scar tissue have led in many cases to unpredictable vertical and horizontal changes, as well as reankylosis requiring further surgical treatment.

Free fat grafts have been shown to be successful in several reconstructive efforts for the temporomandibular joint. As an interpositional tissue spacer in gap arthroplasty or as an adjunct to placing a prosthesis, the fat graft helps to prevent fibrosis and heterotopic bone formation at the articulating interface. The use of temporalis muscle flaps has also been reported as useful in creating barriers for ankylosis cases, but as with most autogenous tissue solutions, it carries with it the possibility of unpredictable scarring and dimensional changes.

Since the mid 1990s, development of newer prostheses to deal with total temporomandibular joint replacement following partial or complete ankylosis release have produced excellent products. This new research and development has been fueled by the technology of other prosthetic replacements of the appendicular skeleton and stricter oversight by the Food and Drug Administration. The materials used, cobalt chrome (CoCr-Mo) for the metal condyle and ultrahigh-molecular-weight polyethylene (UHMWPE) for the fossa, are very hard materials that produce very little wear debris and help to maintain the vertical dimension of the reconstruction. These products are available as a stock prosthesis with some choices in sizing, or as a custom prosthesis (CAD/CAM) whereby the condyle and fossa are fabricated from 3-dimensional generated models. The high acceptance rate and low reoperation rate is fast making this the procedure of choice for the reconstruction of the severely ankylosed deformity.

Case study

A 34-year-old man involved in a motor vehicle accident suffered multiple head and neck injuries requiring long-term intensive care support. Maxillofacial injuries included comminuted symphysis fracture as well as bilateral high condyle fractures. The symphysis fractures were treated in an open manner, but the condyles were treated in closed fashion because of the protected neck injuries. Five

Fig. 7. Case study. (*A*) Preoperative profile view. (*B*) Preoperative facial view.

Fig. 8. Computed tomography scan showing fracture deformity.

Fig. 9. Intraoral vertical defect caused by fractures.

Fig. 10. Surgical splint designed to reestablish vertical dimension.

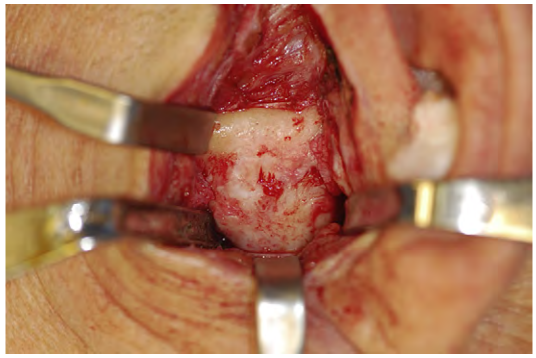

Fig. 11. Complete fibrous and bony ankylosis of left side.

Fig. 12. Initial cut with separation.

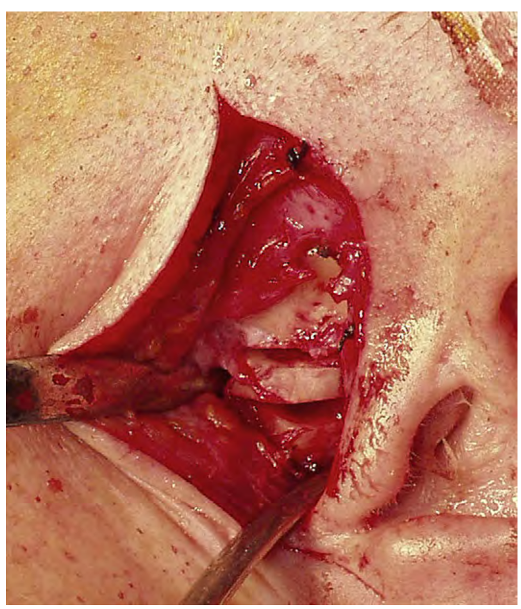

Fig. 13. Additional slices of bone removed to widen the gap.

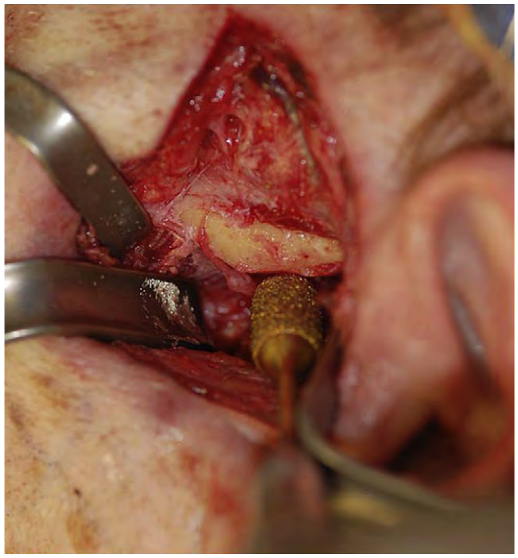

Fig. 14. Preparation of the site for fossa prosthesis placement.

months later the patient presented with a chief complaint of pain and inability to open his mouth (Fig. 7). Computed tomography revealed medially and inferiorly displaced condyles bilaterally, with evidence of bony and fibrous union of the ramus and zygoma (Fig. 8). Clinical examination revealed a collapsed posterior dimension more on the right than on the left, preventing any attempt at prosthetic rehabilitation (Fig. 9).

Study models were taken with difficulty and a surgical splint was fabricated, reestablishing the appropriate vertical dimension (Fig. 10). The patient was taken to the operating room where both

Fig. 15. Prosthetic fossa and condyle in place.

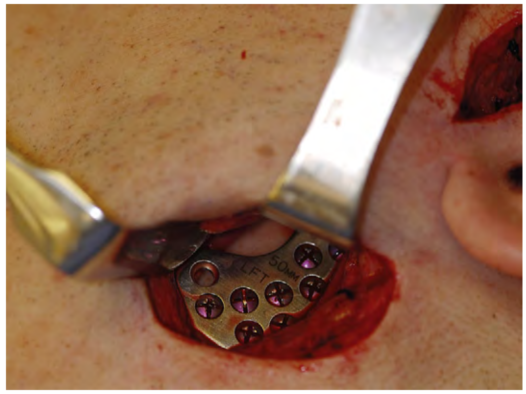

Fig. 16. Securing prosthetic condyle through neck incision.

ankylosis deformities were released and the residual condyles were removed (Figs. 11–14). After generous stripping of the musculature, the mandible was brought inferior and anterior into the prefabricated surgical splint. The prosthetic fossa was then placed through the preauricular access and the condylar prostheses were placed through the neck incision access (Figs. 15–17). The patient was then taken out of intermaxillary fixation. Postoperatively, the patient was immediately placed on intense physical therapy. At 3 months a full lower denture was fabricated as a temporary measure until the patient could afford an implant-supported prosthesis.

Fig. 17. Incisions prior to closure. Left side.

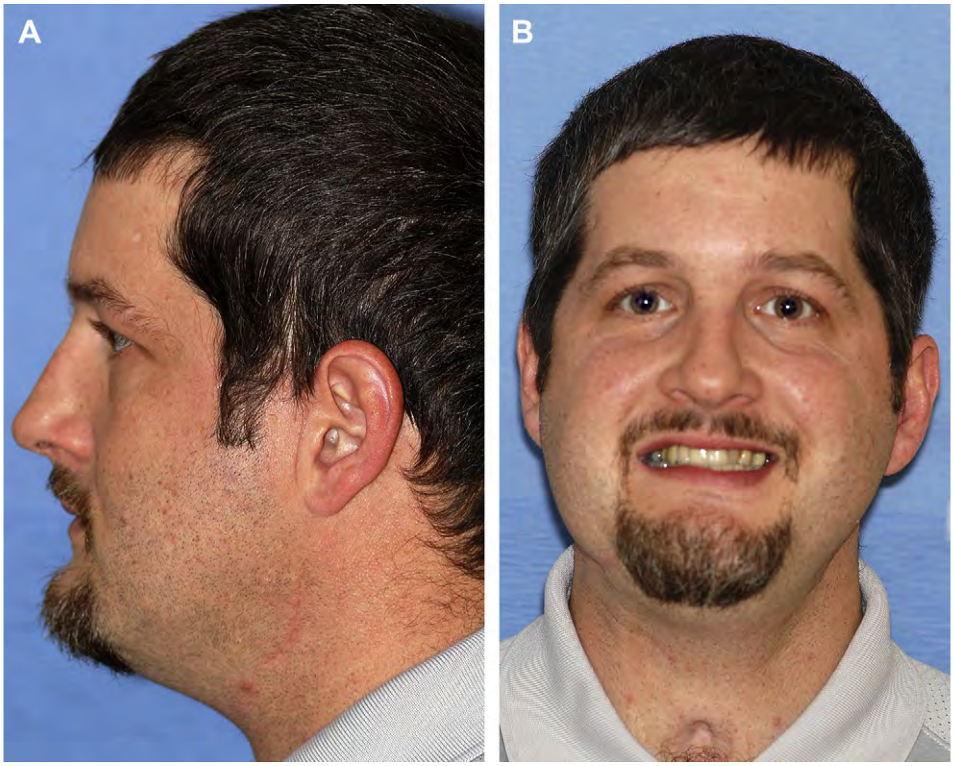

Fig. 18. (*A*) Eighteen-month postoperative profile view. (*B*) Eighteen-month postoperative facial view.

At the 18-month follow-up the patient was opening to 40 mm with no pain or evidence of jaw restriction. The immediate postsurgical occlusal vertical was maintained throughout the postoperative period, and treatment planning for an implant-supported prosthesis was begun (Figs. 18–22).

Fig. 19. Postoperative cephalometric film.

Fig. 20. Maintenance of reestablished vertical dimension.

Fig. 21. Lower prosthesis in place.

Fig. 22. Interincisal of 40 mm 18 months postoperatively.

Summary

Surgical correction of the severely ankylosed temporomandibular joint is one of the most challenging procedures the oral and maxillofacial surgeon will perform. The sheer number of pitfalls that can arise throughout the procedure makes thorough preoperative planning an absolute necessity. A systematic progression through each stage of the procedure will help the surgeon maintain good visualization and increase his or her ability to deal with any complication that may arise. The patient must also be made aware of the importance of his or her cooperation in the success of this procedure, especially in the very important postoperative rehabilitative period.

As with most difficult endeavors, the reward for successful treatment is great. The correction of such a devastating deformity returns normal function back to a previously deformed patient and instills in them a lifetime of gratitude for the person who made it possible.

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Total Reconstruction of the Temporomandibular Joint with a Stock Prosthesis

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Indications for temporomandibular joint (TMJ) reconstruction include bony ankylosis, failed previous alloplastic and autogenous joint replacement, posttraumatic condylar injury, avascular necrosis, posttumor reconstruction, developmental abnormalities, functional deformity, and severe inflammatory conditions that have failed to resolve with conservative treatments. Successful TMJ replacement requires careful preoperative planning, reasonable patient expectations, proper intraoperative technique, regimented postoperative physical therapy, close follow-up, and adequate pain management. Achieving successful TMJ replacement often requires multidisciplinary care from oral and maxillofacial surgeons, pain specialists, internists, physical therapists, and general dentists to optimize patient outcome.

Alloplastic joint reconstruction currently offers several advantages compared with autogenous replacements. These advantages include lack of donor morbidity, reduced intraoperative surgical time, immediate functioning, the ability to correct malocclusion (with bilateral replacement), and, most importantly, improved predictability. The most widely used autogenous graft for TMJ reconstruction is the costochondral graft. Compared with alloplastic joint reconstruction, costochondral grafting has a higher complication rate. Complications include graft resorption, overgrowth, and ankylosis. Alloplastic joint reconstruction allows for a stable platform in which retrognathia and facial asymmetry may be corrected in a single surgical procedure.

Unacceptable failure rates have been reported in previous alloplastic TMJ implant systems, which have provided valuable input for the development of newer implants approved by the US Food and Drug Administration (FDA). Appreciation of biomechanical and orthopedic principals, along with appropriate clinical trials, has helped in the development of safe and effective devices. These devices still have limitations, such as finite life expectancy, limited translation, the development of wear debris, and the size of the devices. Because fewer patients are requiring revision arthroplasty from previous failed devices, it can be expected that more primary joint reconstruction will be performed for conditions such as severe inflammatory arthritides, trauma, and ankylosis. A stock prosthetic device has the advantages of immediate availability, single-stage surgery, no need for recapitulation from a stereolithic model, and lower cost. Contraindications to alloplastic joint placement include the presence of active infection, skeletal immaturity, and severe or compromised bone deformity. Patients with severe bone anatomic discrepancies may be candidates for patient-matched custom implants.

Preoperative planning

Preoperative planning begins with a careful history and physical examination. Documentation should include the number of open and closed TMJ surgeries. Pain scores should be quantified, and

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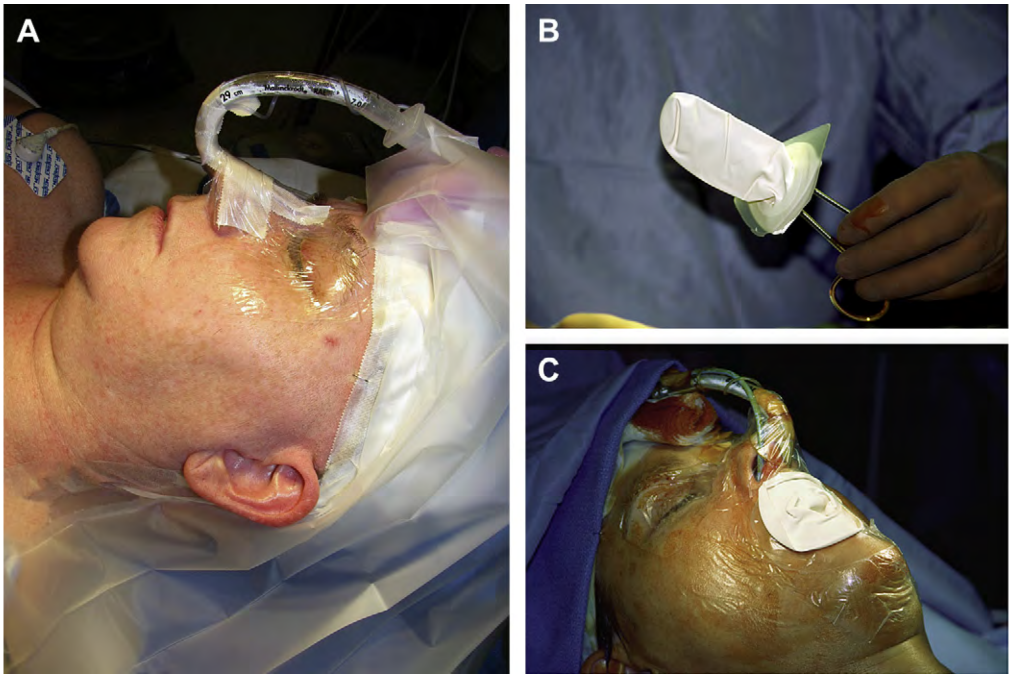

Fig. 1. (*A*) Patient draped. (*B*) Modified urological dressing. (*C*) Urological dressings allowing sterile manipulation of the mandible; also note Tegaderm covering the nares to limit contamination.

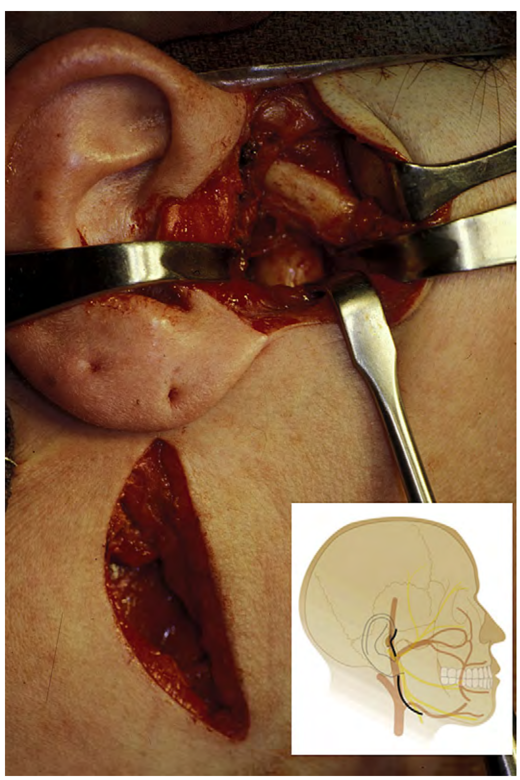

Fig. 2. Endaural and modified retromandibular incision providing access for total joint replacement. (*Inset courtesy of* Biomet Microfixation, Jacksonville, FL; with permission.)

analgesic use should be noted. Patients with a history of multioperated joints and chronic pain may benefit from an evaluation from a pain specialist before surgery. Many patients with severe rheumatic conditions are on immunosuppressive medications. Coordination for the temporary cessation of these medications (eg, glucocorticoids, disease-modifying antirheumatic drugs, and anticytokine medications) in the perioperative period is important to prevent infection and promote healing. Good communication with the patient's rheumatologist is paramount. Many imaging modalities are available to assess the patient. At this institution, all patients receive a panorex and computed tomography scan to visualize the existing bone and bone quality as well as the proximity of adjacent vital structures. The patient is then counseled, and appropriate expectations of function and pain relief are discussed.

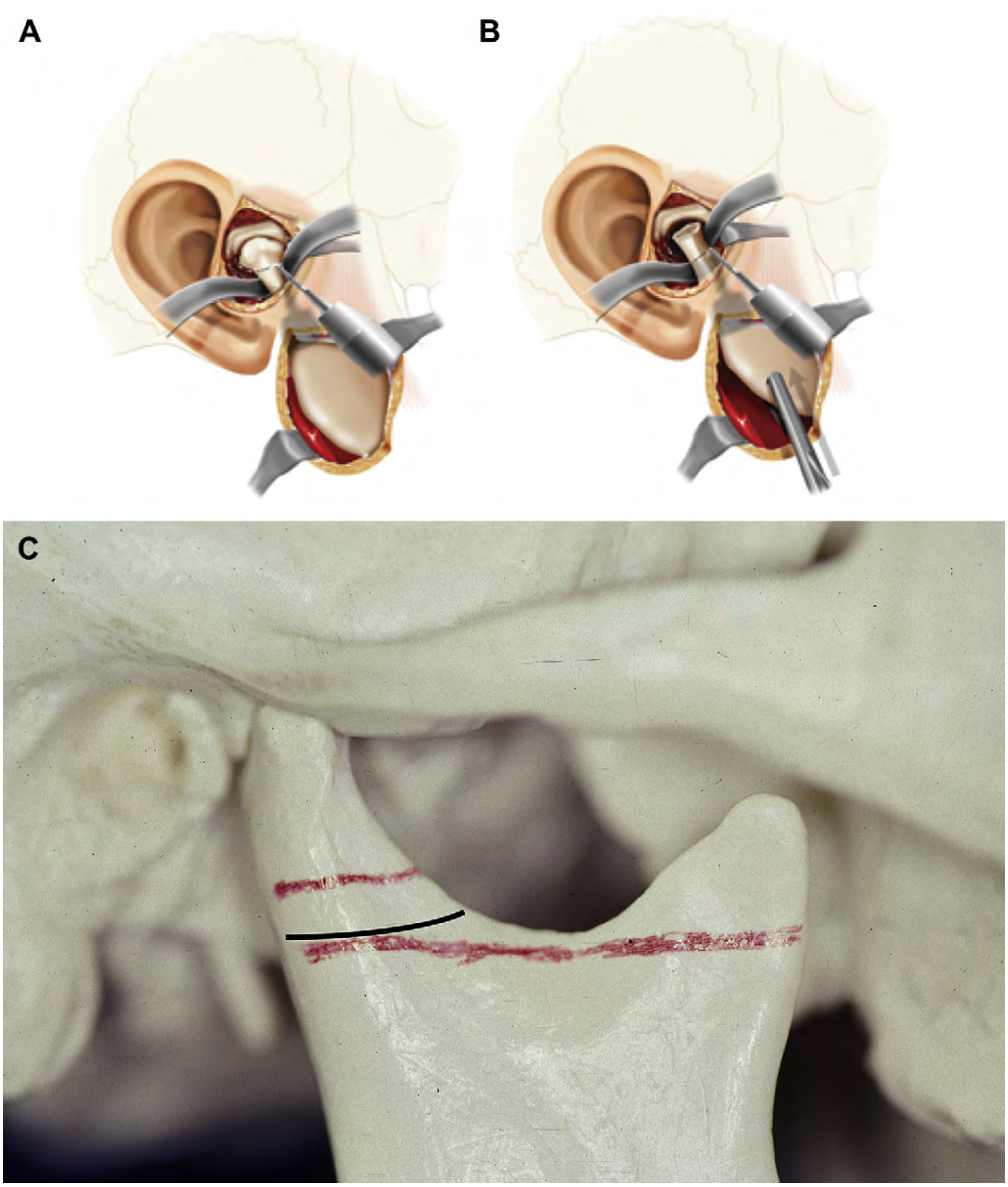

Fig. 3. Two step osteotomy. (*A*) Initial condylectomy with use of Dunn-Dautrey retractors to protect deeper structures. (*B*) Superior repositioning of the ramus to allow for improved access to the second-stage osteotomy and increased distance from the internal maxillary artery. (*C*) Location of 2-step osteotomies; note curvilinear shape of black line if coronoidectomy is not required. ([*A*, *B*] *Courtesy of* Biomet Microfixation, Jacksonville, FL; with permission.)

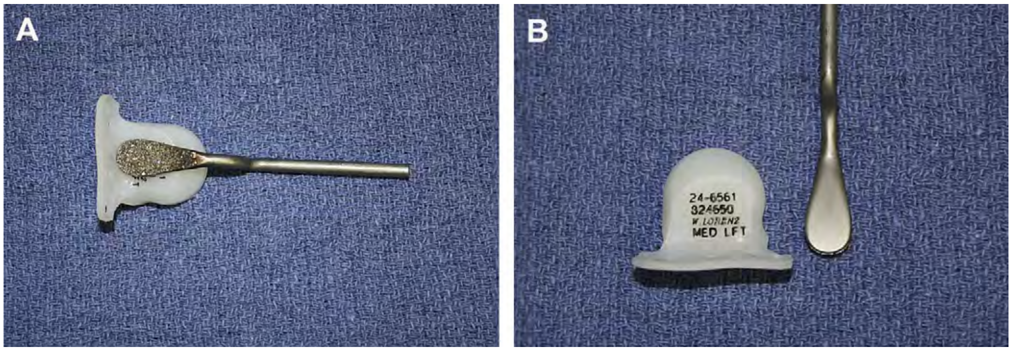

Fig. 4. (*A*, *B*) Rasp overlying fossa, note length of rasp matches width of fossa.

Procedure

Prep and Positioning

Strict adherence to aseptic technique is crucial to minimize postoperative infection. Hair should first be removed from the proposed incision site, typically to the superior portion of the helix. Tape is then used to pull remaining hair back and prevent its entry during the operation. A head wrap is then applied, and the skin is prepped. A urological drape is adapted and used as a sterile barrier to manipulate the mandible during the operation (Fig. 1). Minimizing contamination from the oral cavity is critical to reduce postoperative infections. Once this is complete, the ear canal is irrigated with antibiotic solution. A preoperative antibiotic should be given during this time to ensure adequate tissue levels before incision. At this institution, patients are given cefazolin and metronidazole unless a penicillin allergy is present, in which case clindamycin is the prophylactic antibiotic of choice.

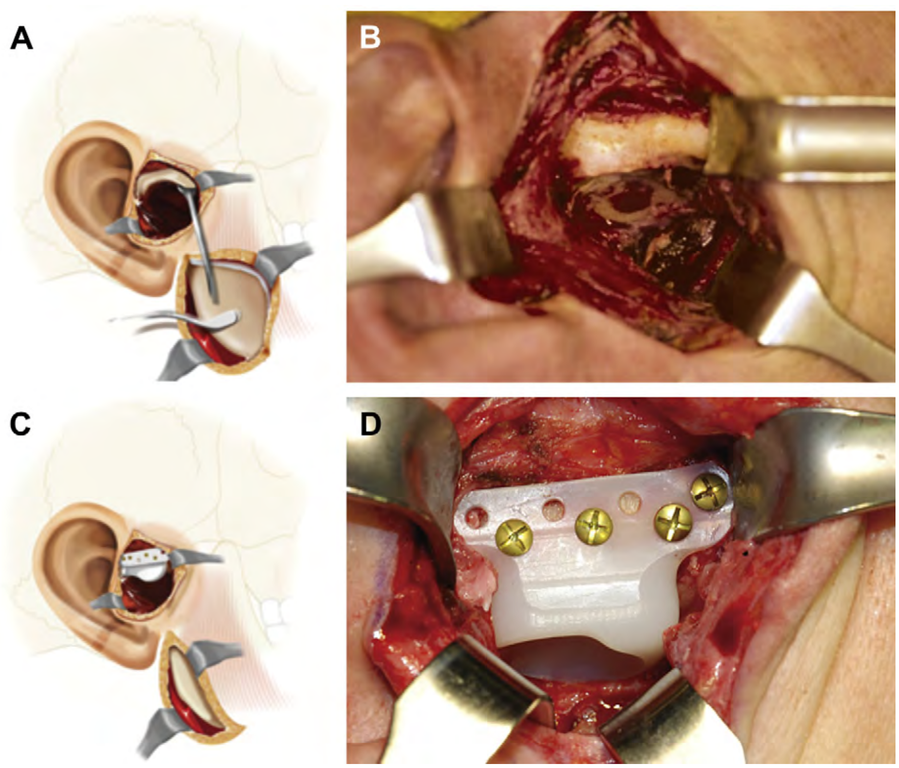

Fig. 5. (*A*) Flattening of articular eminence and lateral surface of ramus in preparation of prosthesis. (*B*) Prepped articular eminence. (*C*) Proper position of fossa. (*D*) Intraoperative placement of fossa. (*Courtesy of* Biomet Microfixation, Jacksonville, FL; with permission.)

Attention to sterile technique, especially when alternating between the surgical site and the oral cavity, is the most important step in preventing prosthetic infection.

Exposure

Attention is first directed to the preauricular region, where an endaural incision is used (Fig. 2). This approach is chosen both for its improved cosmetic outcome and because the incision is farther from the prosthesis. The endaural incision requires a stepped dissection to the joint, which increases the tissue coverage over the implant. Once the TMJ is fully dissected, the ramus is then exposed via a modified retromandibular incision. The neck is exposed before any osteotomy, to ensure rapid access to the underlying vasculature if difficult-to-control bleeding is encountered. The incision is marked by placing a gloved finger from the lobule of the ear to the angle of the mandible. A marking pen is then used to identify the incision 1 finger breadth below the angle of the mandible to avoid the marginal mandibular nerve. The incision starts approximately 1 cm below the lobule of the ear and continues to the premasseteric notch. Dissection is carried down through the superficial layer of the deep cervical fasci, with the aid of a nerve stimulator until the sternocleidomastoid muscle is identified. From this point, a Kelly is used to bluntly dissect anterior to the sternocleidomastoid muscle. Then, the direction of the dissection is changed to parallel the inferior border of the mandible until the posterior belly of the digastric is identified. A 15 blade is used to incise the pterygomasseteric sling along the avascular aponeurosis. With the aid of an Obwegeser periosteal elevator, the masseter is cleanly dissected off the mandible to expose the entire ramus, allowing communication between

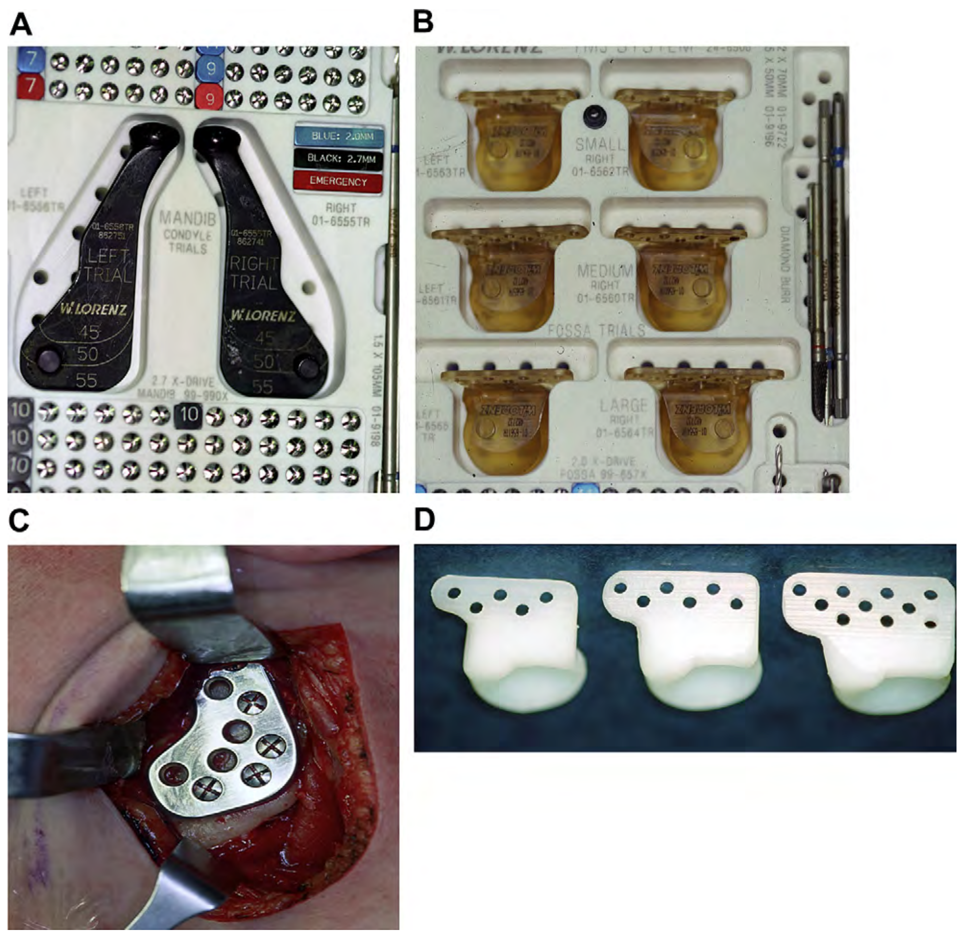

Fig. 6. Instrumentation. (*A*) Condylar implant sizer. (*B*) Fossa sizers. (*C*) Standard implant placed with 2.7-mm screws; 3.1-mm emergency screws are available. (*D*) Three sizes of fossa implant. The implant is made of ultrahigh-molecular-weight polyethylene. The fossa is set with 2.0-mm screws.

the 2 incisions in a safe subperiosteal plane. Care is taken to minimize trauma between the small bridge of tissue between the 2 incisions because the facial nerve travels in this tissue.

Osteotomy

A 2-step osteotomy has been developed to minimize risk to the internal maxillary artery and ensure adequate bone removal for the fossa component (Fig. 3). With the TMJ fully exposed, 2 Dunn-Dautrey retractors and a condylar neck retractor are placed deep in the condylar neck to aid in visualization and protect deeper structures. A 1-mm fissure bur is used to perform the condylectomy. An osteotomy is performed by first starting at the midpoint of the condylar neck, while sparing the medial cortex. The cut is then extended both anteriorly and posteriorly. A T-bar osteotome is then used to complete the condylectomy. The condyle is then grasped with a bone-holding forceps and the lateral pterygoid is carefully dissected free. At this point, significant bleeding may occur, and the surgeon should be ready to control any hemorrhage with the aid of hemostatic agents. Once the condyle is removed, this creates space and allows the surgeon to superiorly reposition the ramus. This maneuver allows easier access to the second step of the osteotomy and places this bone cut away from the internal maxillary artery. To ensure sufficient space for the fossa, bone should be removed to just below the most inferior point of the coronoid notch by making a curvilinear shaped osteotomy. Again, great care should be taken to protect deep soft tissue structures with the aid of the Dunn-Dautrey retractors, considering that the internal maxillary artery normally runs approximately 3 mm medial from the midsigmoid notch. This osteotomy is performed in a similar fashion to that described earlier, with approximately 90% of the bone removed with the fissure bur and completion accomplished with a T-bar osteotome.

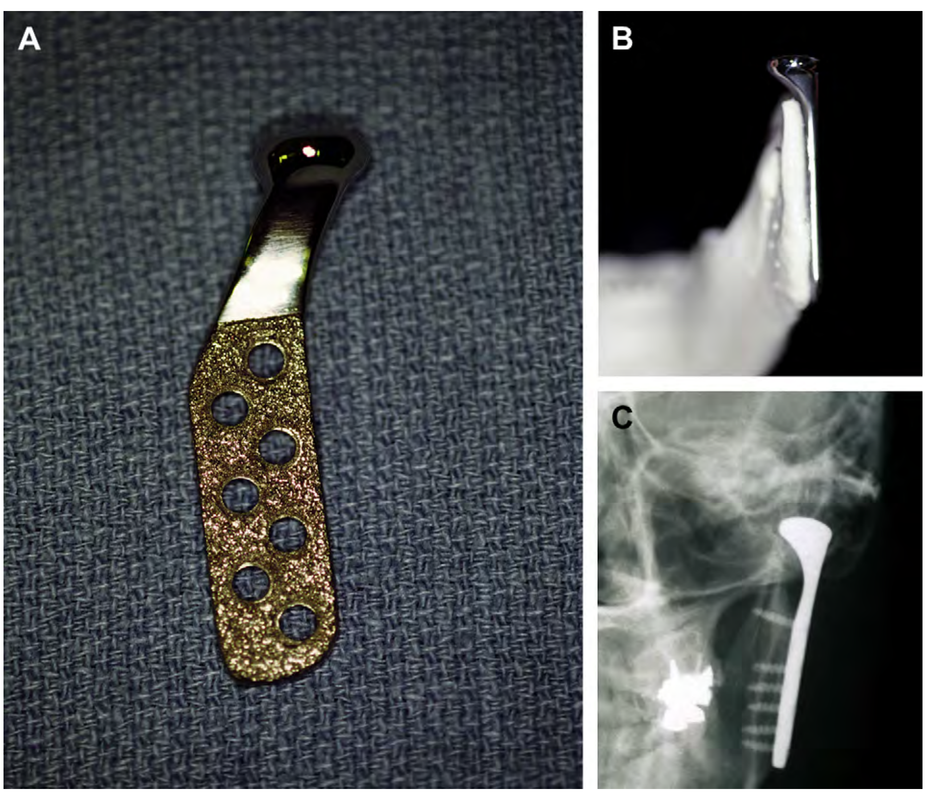

Fig. 7. (*A*) Narrow mandibular prosthesis, which is an alloy of chromium, cobalt, and molybdenum, with a titanium-coated medial surface. (*B*) Correct position of prosthesis. (*C*) Good screw and prosthesis position.

Fossa Placement

Secure fossa placement requires tripod stability, which is achieved by reducing the articular eminence with a reciprocating rasp (Fig. 4). The cutting surface of the available rasp matches the width of the 3 available fossa sizes. Because most anatomic variation is found in the articular eminence, once this area is flattened, a stock fossa is easily secured in place (Fig. 5). Correct angulation is critical to minimize dislocation and allow maximal opening. The fossa component should parallel the Frankfurt horizontal plane. A sizer is available to aid in fossa selection. Placement is then initiated by securing the fossa with 2 screws (Fig. 6). Correct alignment is checked before additional screws are placed. The tip of a nerve stimulator can be used to determine that adequate bone is available along the zygomatic arch before the final screws are placed.

Placement of Mandibular Component

Before the condylar replacement, the patient is placed in intermaxillary fixation (IMF). Great care should be taken to avoid contamination of the surgical wounds from the oral cavity. Contamination is avoided by using a separate instrument set, reprepping and draping the patient, and glove changes before returning to the surgical wounds. Once the patient has been placed in IMF, a sizer is used to choose the appropriate implant length. The available implants include 45, 50, and 55 mm (see Fig. 6). The prosthesis is also available in narrow and standard; the standard has more available screw holes for patients with compromised bone. Care should be taken to ensure that the screw holes used do not encroach on the inferior alveolar nerve, which is easily accomplished with the aid of standard radiographs. Once the implant is selected, it should be seated in the posterior aspect of the fossa to allow

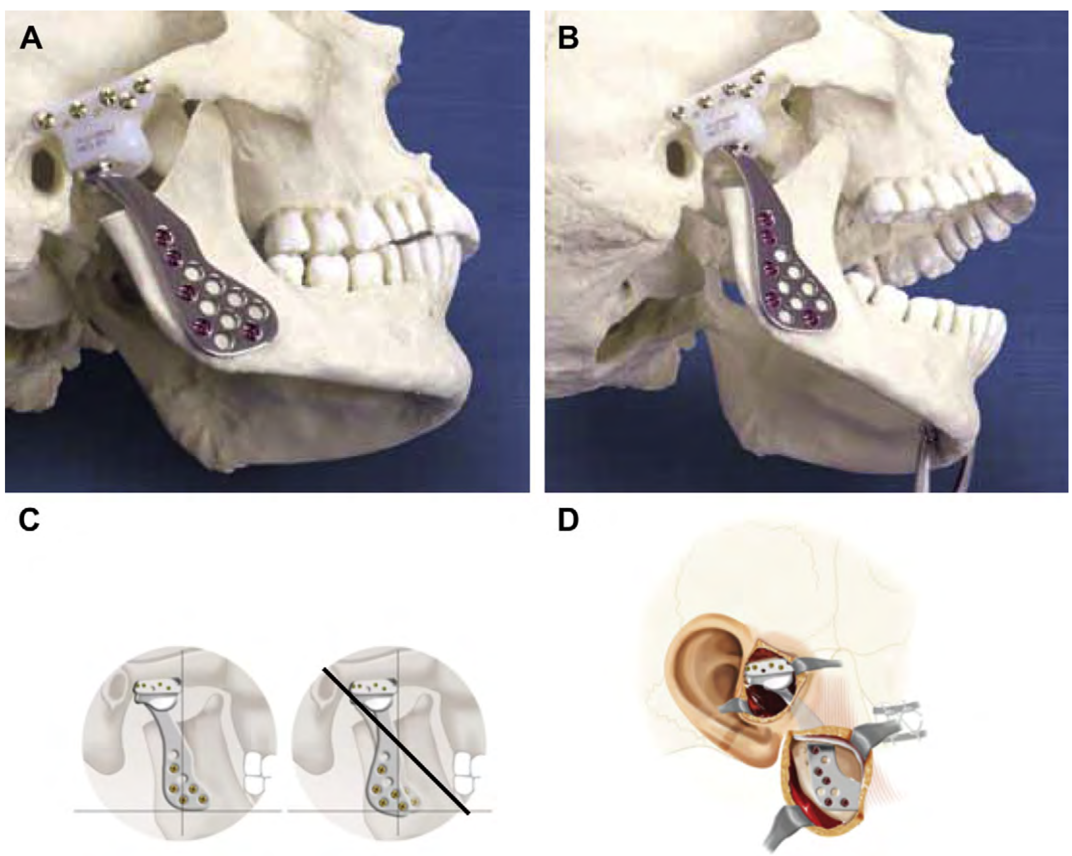

Fig. 8. (*A*, *B*) Pseudotranslation of the prosthesis. (*C*) The left diagram shows correct posterior position of the prosthesis, whereas the right diagram shows incorrect positioning. (*D*) Correction position of prosthesis with patient in IMF. (*Courtesy of* Biomet Microfixation, Jacksonville, FL; with permission.)

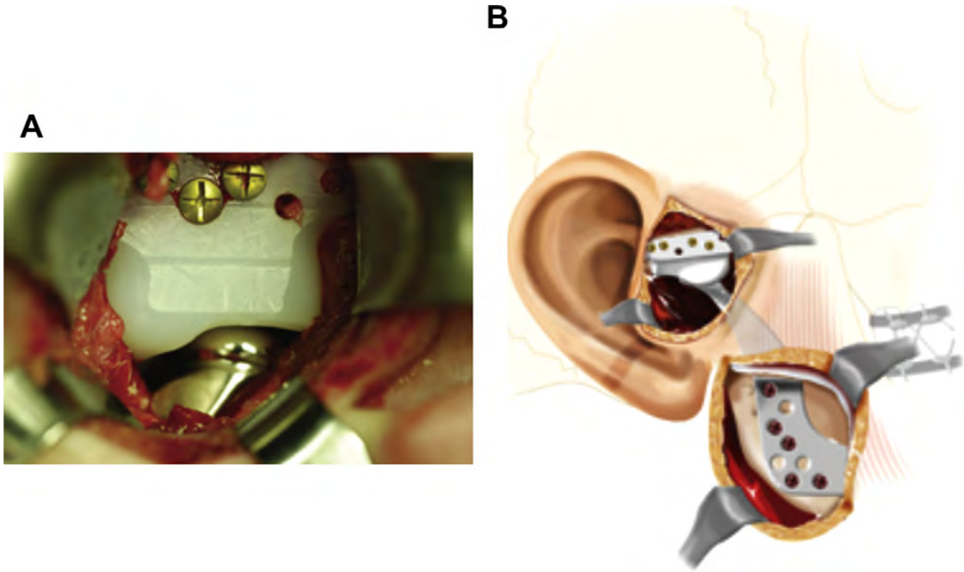

Fig. 9. (*A*) Condyle correctly seated in fossa. (*B*) Prosthesis correctly seated. (*Courtesy of* Biomet Microfixation, Jacksonville, FL.)

for maximal incisal opening (Fig. 7). Two screws are placed to fixate the prosthesis, the wounds are covered with antibiotic-soaked sponges, and the occlusion is checked. Again, care is required to avoid cross-contamination from the oral cavity. At this time, the surgeon should also check for anterior dislocation. Once satisfactory occlusion is achieved, the prosthesis is then fixated with 4 to 6 screws (Figs. 8 and 9).

Fig. 10. Well-healed incisions.

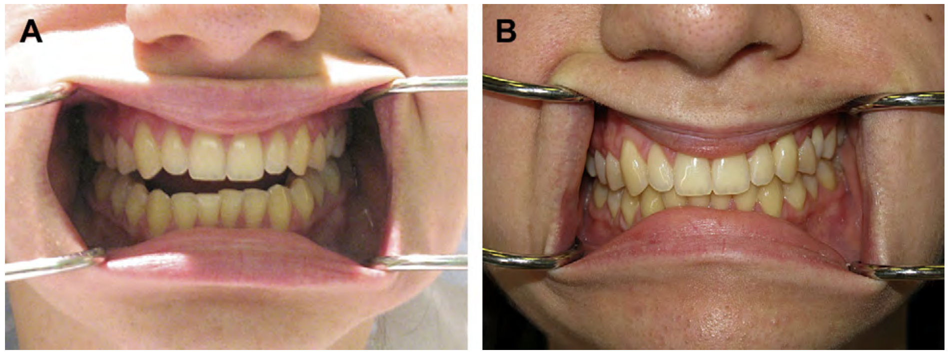

Fig. 11. (*A*) Preoperative occlusion of patient 1. (*B*) Postoperative occlusion of patient.

Closure

Closure begins once all wounds have been thoroughly irrigated with antibiotic-impregnated saline. Hemostasis is confirmed, and the endaural incision is closed in layers. The neck incision is again irrigated, hemostasis is confirmed, and the incision is closed first with the superficial layer of the deep cervical fascia. The pterygomasseteric sling is left to passively reattach. The skin is then closed, and dressings are placed (Fig. 10). Once the wounds are dressed, the IMF wires or screws are removed.

Postoperative Care

Postoperative radiographs should be obtained before patient discharge to confirm correct angulation, screw position, and condylar seating. Patients are seen 10 days following discharge for suture removal, and passive jaw motion is encouraged. Active jaw physical therapy may be indicated for patients and is typically initiated for 4 to 6 weeks following surgery. A standardized follow-up regimen should ensue, with annual radiographic assessment of the prosthesis.

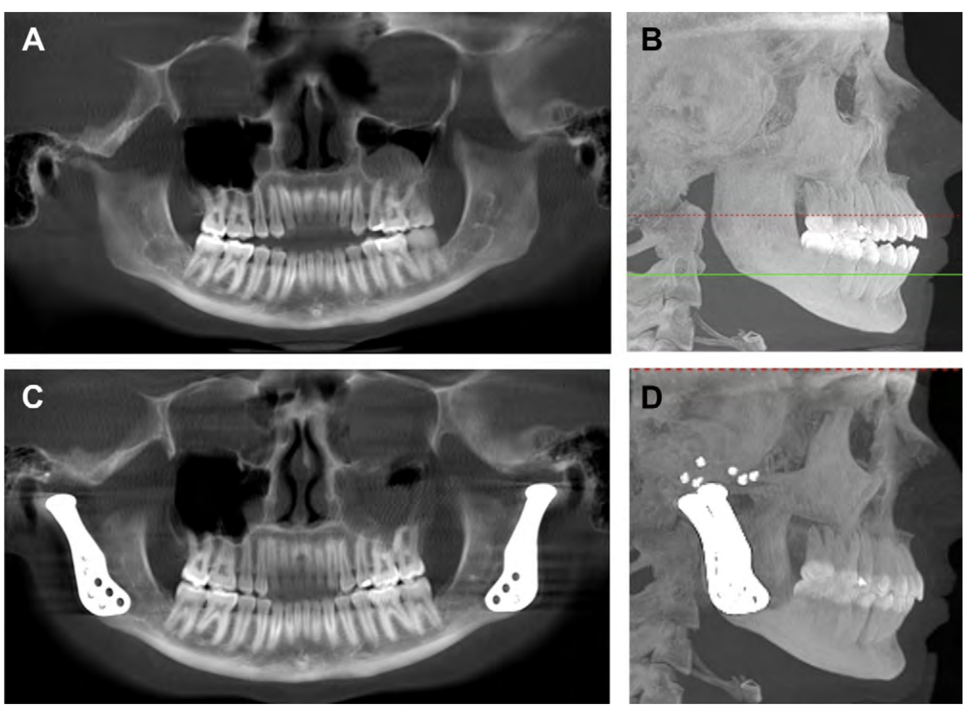

Fig. 12. (*A*, *B*) Patient 1 before surgery. (*C*, *D*) Patient 1 after surgery.

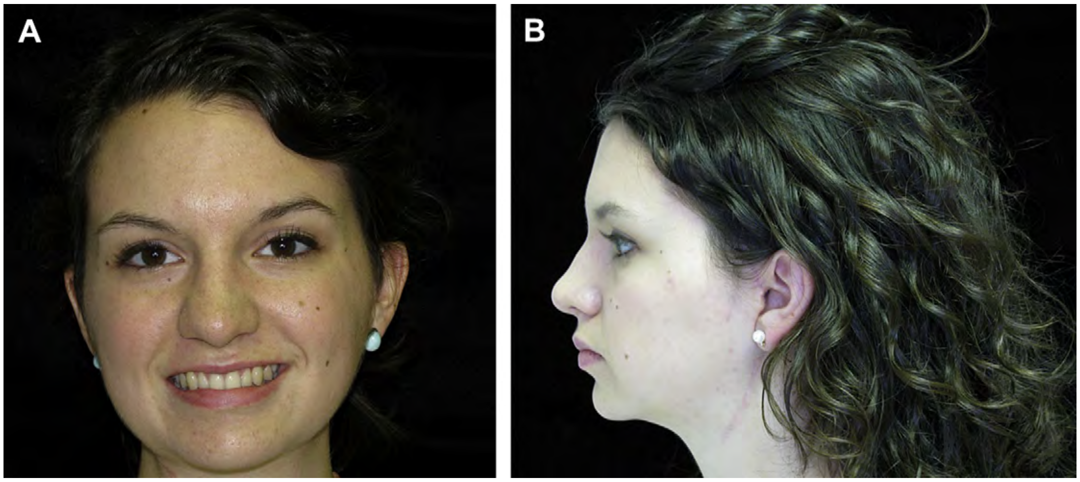

Fig. 13. Patient 1 after surgery.

Experience

In 2005, the FDA approved the Biomet TMJ prosthesis following a 10-year prospective Investigational Device Exemption study. Data from 224 cases are available. After 3 years, patients were found to have a significant improvement in pain, with preoperative scores decreasing from a mean of 8.5 to 2.8 out of 11. Mouth opening improved from 20.1 mm to 29.3 mm at 3 years. Most importantly, patient satisfaction scores were high: 99% of patients stated that, in hindsight, they would have the surgery again. Westermark recently reported on his experience with this prosthesis. Twelve patients were followed for 8 years. At the 1-year follow-up, mean jaw opening increased from 3.8 mm to 30.2 mm. Joint-related pain was eliminated in all but 2 patients. These 2 patients reported persistent muscle pain. No postoperative infections or device failures were seen. Additional trials are ongoing.

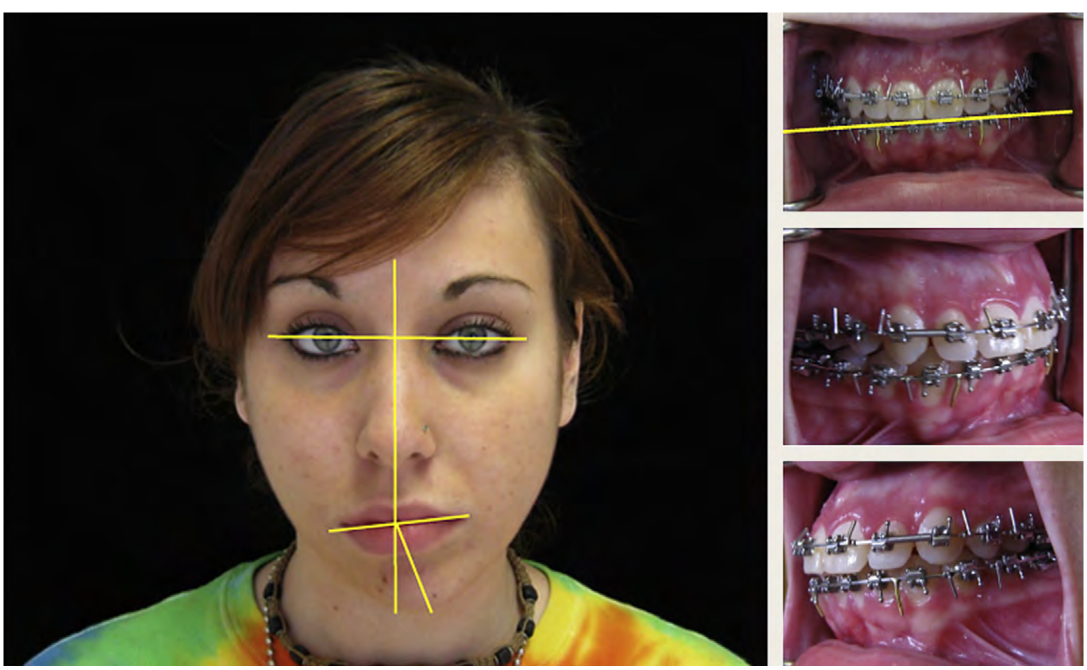

Fig. 14. Patient 2 before surgery. Note occlusal cant and facial asymmetry.

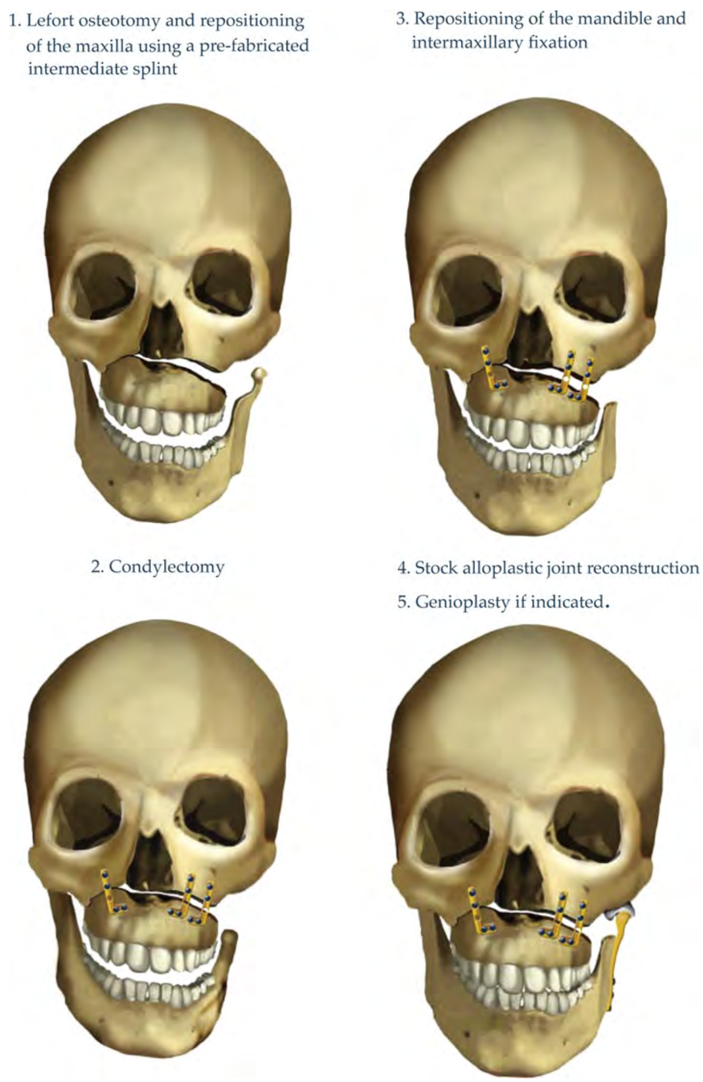

Fig. 15. Protocol for single-staged correction of facial asymmetry (secondary to condylar disorder) with stock joint replacement.

Case 1

A 22-year-old woman diagnosed with rheumatoid arthritis notes progressive changes in occlusion and new anterior open bite (Fig. 11A). Radiographs reveal bilateral severe degenerative changes of the TMJ and collapse of the posterior ramal height. Postoperative photographs show reestablishment of a class 1 occlusion (see Fig. 11B). Postoperative radiographs reveal bilateral total joint replacement in good position (Figs. 12 and 13).

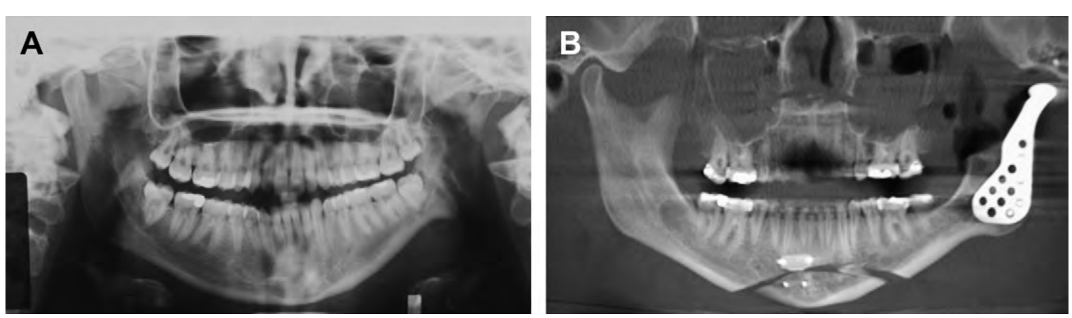

Fig. 16. (*A*) Preoperative panorex of patient 2. (*B*) Postoperative panorex of patient 2.

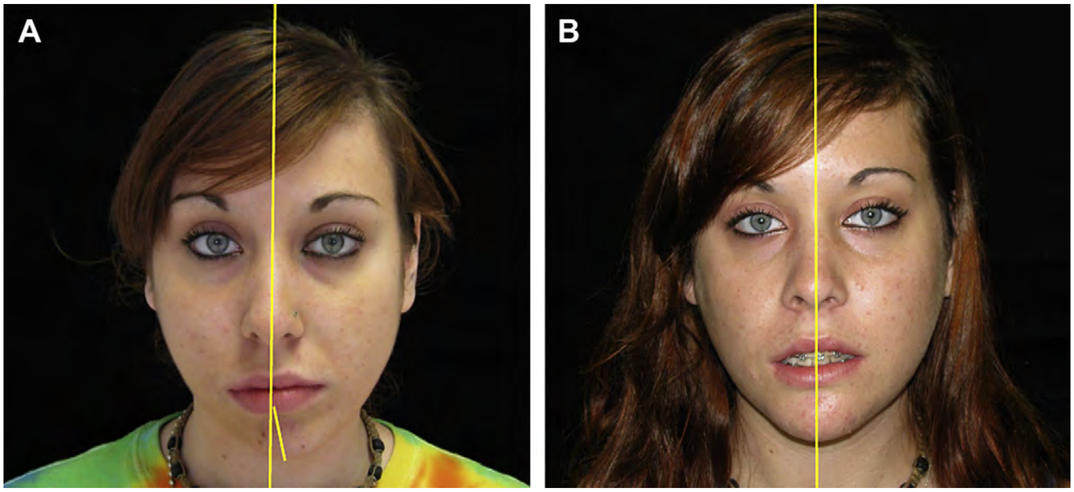

Fig. 17. (*A*) Patient 2 before surgery. (*B*) Patient 2 after surgery; note correction of facial asymmetry.

Case 2

Eighteen-year-old skeletally mature woman with a history of psoriatic arthritis, trismus, and facial pain (Fig. 14). Radiographs reveal marked left condylar degeneration and ankylosis. Secondary facial asymmetry has resulted from her condylar disorder, as seen in the clinical photographs. The patient underwent our protocol for the correction of facial asymmetry secondary to TMJ disorder (Fig. 15). Postoperative radiographs show corrected skeletal asymmetry (Figs. 16 and 17).

Summary

Stock prosthetic TMJ implants provide a safe, predictable, efficient, and cost effective means for joint reconstruction.

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Patient-Fitted ("Custom") Alloplastic Temporomandibular Joint Replacement Technique

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Alloplastic temporomandibular joint (TMJ) replacement is indicated as management of the following conditions:

a. Inflammatory arthritis involving the TMJ not responsive to other modalities of treatment
b. Recurrent fibrosis and/or bony ankylosis not responsive to other modalities of treatment
c. Failed tissue grafts (bone and soft tissue)
d. Failed alloplastic joint reconstruction
e. Loss of vertical mandibular height and/or occlusal relationship due to bony resorption, trauma, developmental abnormalities, or pathologic lesions.

At present, there are two types of alloplastic TMJ replacement devices available to the reconstructive surgeon: "stock" and patient-fitted (ie, "custom"). Both have fossa and ramus/condyle components, which are fixated and stabilized to the temporal bone and the lateral aspect of the ramus of the mandible, respectively, with bicortical screws.

The host fossa and ramus bone must be altered when implanting stock device components, or they must be bent or shimmed with bone or alloplastic cement to develop close host bone adaptation to the device components. Both of these maneuvers can lead to component material fatigue or overload, which promotes early failure under functional loading and, more concerning, allows micromotion of these altered or shimmed components that can interfere with osseointegration. Micromotion leads to the formation of a fibrous connective tissue interface between the altered component and the host bone, which results in early loosening of that component and potential early catastrophic or certain later premature device failure.

Because they are designed and manufactured for each specific anatomic situation, patient-fitted, or "custom," alloplastic TMJ devices conform to any unique anatomic configuration, and require no significant host bone alteration or supplementation to achieve initial implantation stability. Because the components interface accurately with the host bone, the screw fixation secures the components to the host bone, mitigating any micromotion and maximizing the opportunity for osseointegration of the components and fixation screws; thus, there is greater potential longevity of "custom" devices under normal mandibular functional stresses.

This article provides the reader with an illustrated technique for placement of "custom" alloplastic TMJ replacement device components.

Financial disclosure: Dr Mercuri has stock ownership and is a paid Clinical Consultant for TMJ Concepts (Ventura, CA).

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Preparation for surgery

Avoiding contamination of the surgical site is critical during any alloplastic TMJ replacement surgery; therefore, it is essential that complete sterility be maintained at the implantation sites throughout the procedure. The following patient preparation should be considered.

- The patient should be directed to thoroughly wash and rinse their hair the night before surgery with a mild shampoo and avoid the use of hair spray or styling gels the day of the surgery.
- As with any presurgical antibiotic prophylaxis regimen, intravenous antibiotics (eg, cefazolin 1 g, or clindamycin 600 mg) are begun 1 hour preoperatively and are maintained on an appropriate intravenous dosing schedule during the postoperative hospital course. This regimen is followed on discharge by 1 week of oral antibiotic (eg, cephradine 500 mg, clindamycin 300 mg) at the appropriate dosage.
- Anti-inflammatory steroid therapy to minimize edema may be started preincision (8–10 mg intravenous dexamethasone) and continued postoperatively as with other reconstruction or orthognathic surgery.
- Anesthesia may be delivered via a nasoendotracheal tube sutured to the nasal septum (2-0 silk), and the anesthesia tubing and equipment can be positioned near the patient's feet. This arrangement allows for the draping that follows to decrease the potential for contamination and permits easier head movement in bilateral cases (Fig. 1).
- After the patient is anesthetized and the airway secured, the eyes should be lubricated and protected to prevent corneal abrasion (Fig. 2).
- Any hair that could become involved in the surgical field should be carefully arranged and/or parted to facilitate the skin incision. If the hair is to be sheared, care should be taken to avoid cutting or nicking the skin in the area of the surgical incision.
- After shearing the hair to above the ear, the remaining hair should be pulled away from the preauricular and surrounding areas and up toward the crown of the head.
- Using foam tape, the head should be wrapped circumferentially (forehead–above the ear–occiput) so that the hair is under the tape and off the skin over the preauricular incision site(s) (Fig. 3).
- The auditory canal(s) and tympanic membrane(s) should be inspected with an otoscope to ensure there is no preoperative infection and to document any presurgical pathology.
- The external auditory canal on the surgical side should be occluded. A cotton pledget moistened with sterile mineral oil is one option that can be utilized.
- Maxillomandibular fixation appliances (eg, arch bars, Ivy loops) should be applied prior to skin preparation and draping.
- All nonsterile maxillomandibular fixation instruments should be retained on a separate Mayo stand for use later in the procedure when the patient is placed in the final occlusion before device implantation.
- In unilateral cases, after appropriate skin preparation, a plastic adhesive isolation drape (eg, 1010 Steri-drape [3-M, St. Paul, MN, USA]) from the contralateral submental area to the ipsilateral temporal area isolates the mouth from the sterile surgical field. This type of draping allows access to the oral cavity while maintaining sterility of the implantation sites during application of intermaxillary fixation later in the procedure (Fig. 4).
- In bilateral cases, the mouth is first sealed with a plastic adhesive occlusive dressing (Tegaderm; 3-M or Opsite [Smith and Nephew, London, UK]) (Fig. 5).
- The nasotracheal tube and the nose can be further isolated using bilateral 1010 Steri-drapes, as described above; then the loose ends can be folded together over the nasotracheal tube and nose in a sterile fashion, and secured with Steri-strips (3-M).

Incisions

Standard preauricular and retromandibular incisions are needed to access the TMJ area and the mandibular ramus, respectively, and are described elsewhere in this volume.

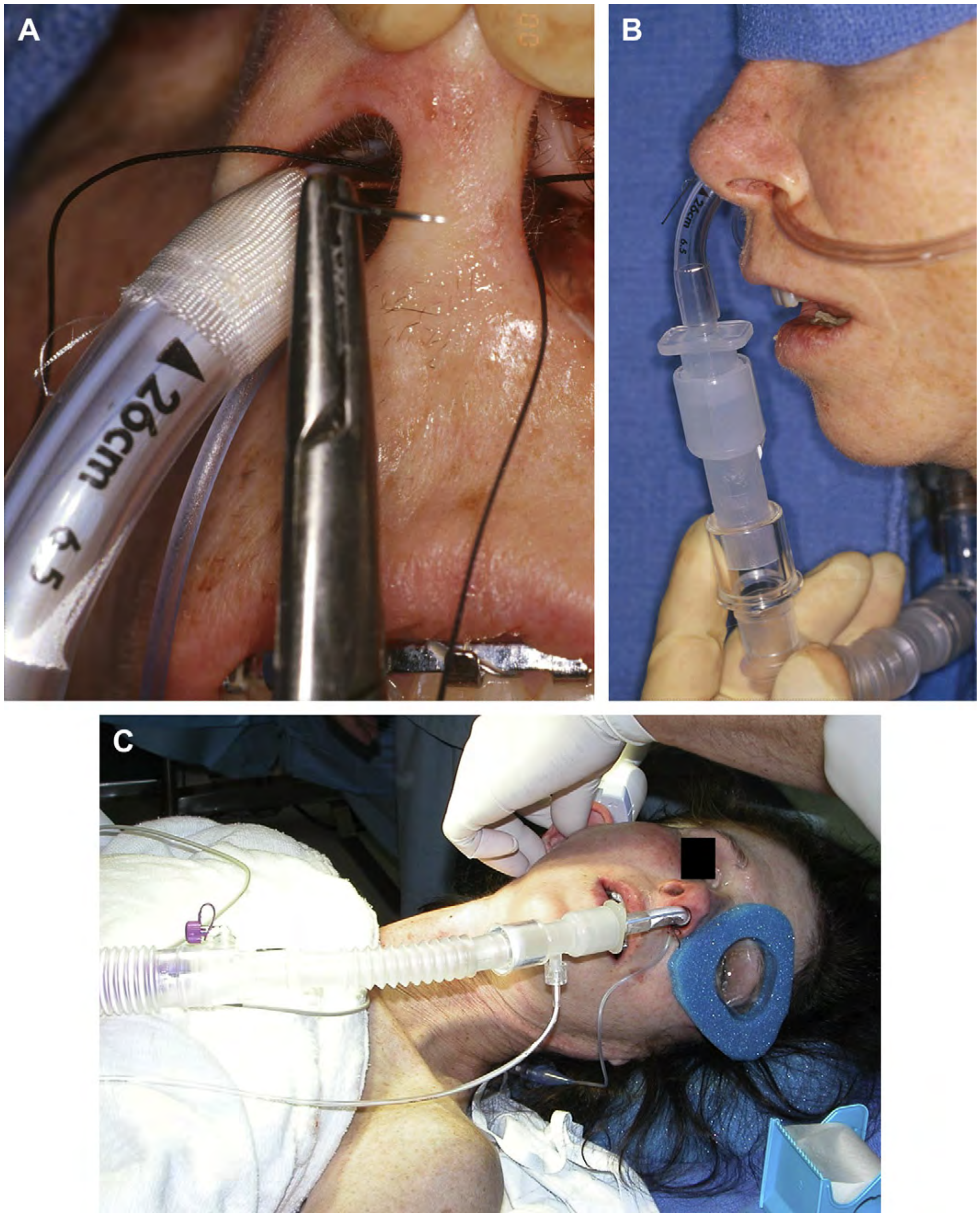

Fig. 1. (*A*) A 2-0 silk suture through nasal septum is tied around the nasoendotracheal tube to secure it in place during surgery. (*B*) Nasoendotracheal tube is secured to nasal septum with 2-0 silk suture and brought inferiorly away from the surgical sites. (*C*) Orientation of the anesthesia tubing and equipment toward the foot of the patient.

Condylar resection

- There must be a minimum of 15 mm between the mandibular condylar resection and the height of the articular eminence area to accommodate the anterior flange of the fossa component of the device (TMJ Concepts, Ventura, CA, USA) (Fig. 6).
- The distance from a known point at the inferior border of the mandible (eg, antegonial notch) to the resection line can be measured on the SL model and transferred to the patient. It is important that this measurement and cut be made accurately so as not to remove more mandibular bone than necessary or involve the inferior alveolar neurovascular bundle (Fig. 7).

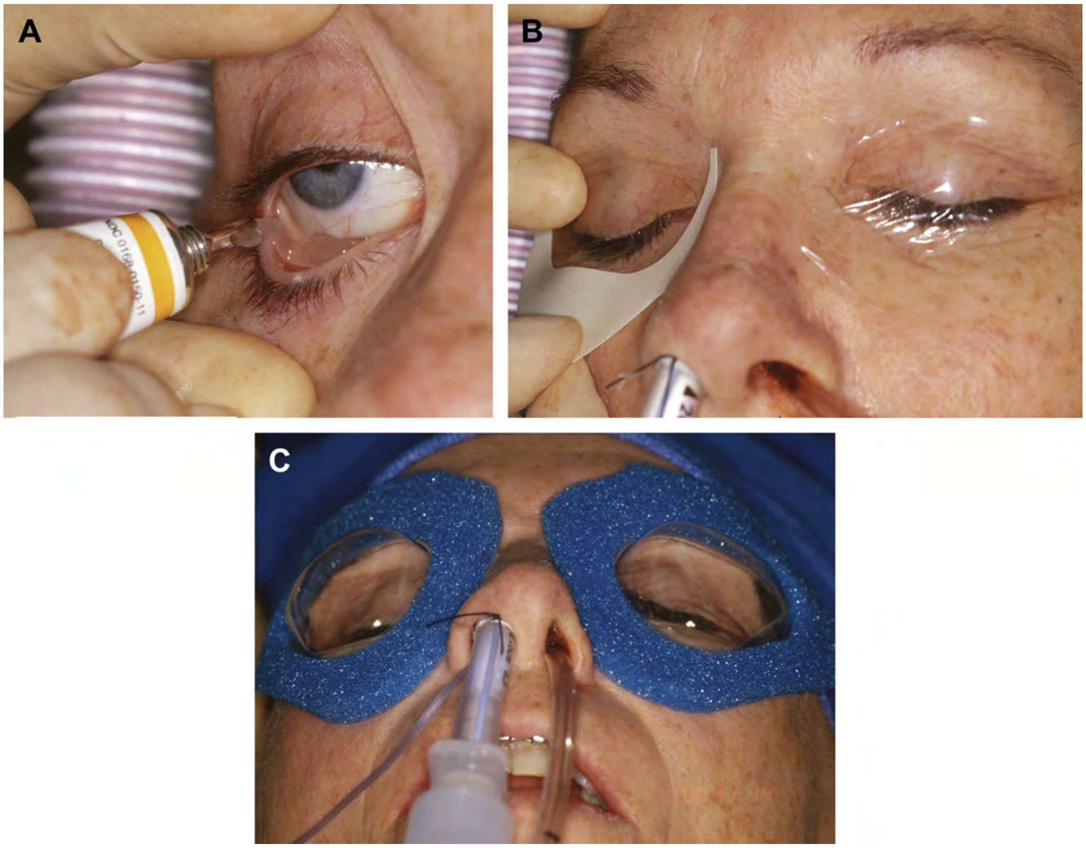

Fig. 2. (*A*) Lubrication of the eye. (*B*) Eyes taped shut. (*C*) Application of plastic goggles to protect the eyes during surgery.

Fig. 3. The head is wrapped circumferentially with foam tape (forehead–above the ear–occiput) so that the hair is under the tape and off the skin over the preauricular incision site. Note the sterile mineral oil-cotton occlusive dressing in the external auditory canal.

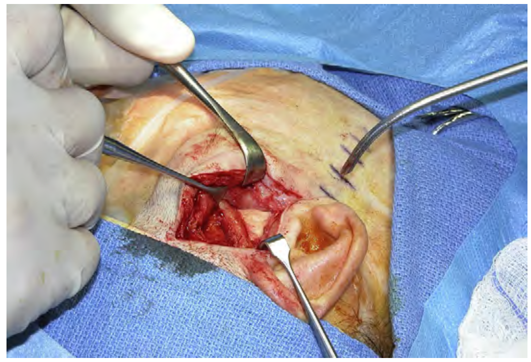

Fig. 4. Plastic adhesive isolation drape (eg, 1010 Steri-drape [3-M, St Paul, MN, USA]) from the contralateral submental area to the ipsilateral temporal area anterior to the surgical site isolates the surgical field from the nose and anesthesia equipment.

Fig. 5. The mouth is isolated with a plastic adhesive occlusive dressing (Tegaderm, 3-M [St Paul, MN] or Opsite [Smith and Nephew, London, UK]).

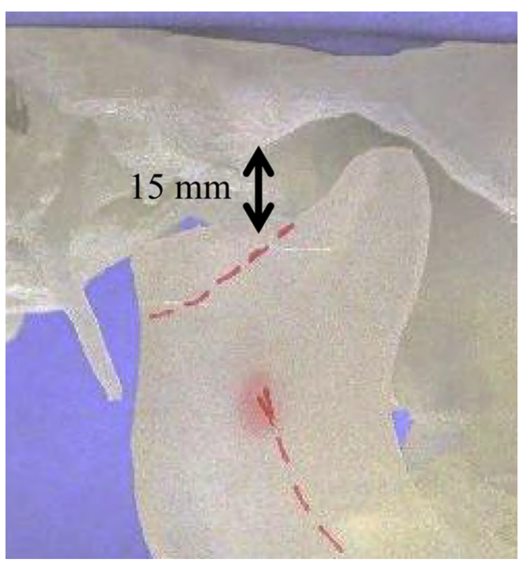

Fig. 6. There must be a minimum of 15 mm between the mandibular condylar resection and the height of the articular eminence area to accommodate the anterior flange of the fossa component (TMJ Concepts, Ventura, CA, USA).

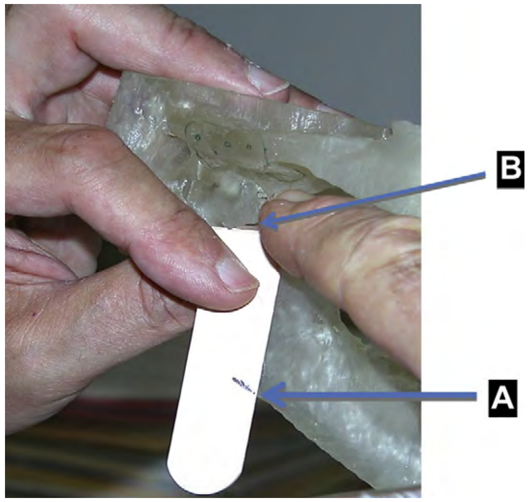

Fig. 7. Measurement from a known point at the inferior border of the mandible (A) to the resection line can be made on the SL model (B). Note tongue blade template that can be sterilized for use during the operation.

- The superior level on the ramus for resection of the condyle is determined preoperatively on the anatomic bone model during the workup. A template can be fashioned prior to surgery (eg, suture pack foil, tongue blade, ruler) to ensure the proper location of this cut.
- The model also assists the surgeon in determining whether the coronoid process is elongated and could therefore interfere with postimplantation mandibular function. If the coronoid process is elongated, it can be removed as well at this stage of the procedure.
- The position of the ramus cut is marked using a marking pen, and a short-blade oscillating saw with copious irrigation is used to separate the proximal segment containing the condyloid processes (and hyperplastic coronoid, if necessary) from the ramus.
- Once the proximal condyloid process segment (and coronoid) is separated, the proximal segment is brought lateral to the ramus with a Seldin elevator. Any remaining lateral pterygoid muscular attachment from the condyle (and temporalis muscle from the coronoid) is removed carefully before attempting to deliver the condyle from the wound. To avoid excessive muscle oozing, an electrocautery needle tip against the pterygoid fovea bone of the condyle (and the coronoid process) can be used to strip the muscle attachments.

Fossa preparation

- The residual fossa is thoroughly debrided of all soft tissue posteriorly to the tympanic plate (g in Fig. 8), anteriorly to the remnant of the articular eminence (c) of the temporal fossa, and medially to the medial ridge of the fossa (d) where the medial capsule attaches superiorly to the temporal bone (see Fig. 8). This step is extremely important to ensure that the fossa component lies in direct contact with the remnant fossa bone, especially medially, to assure the proper relationship between the condylar head of the ramus component and the articulating surface of the fossa component.

Setting the occlusion

- Care must be taken not to contaminate the surgical sites during this procedure. It is recommended that the individual applying the intermaxillary fixation (IMF) change his or her gown and gloves before returning to the sterile field.
- Care must also be taken that none of the instruments used intraorally are reintroduced to the sterile field. Having a separate Mayo stand with dedicated IMF instrumentation and suction, as mentioned earlier, precludes such problems.

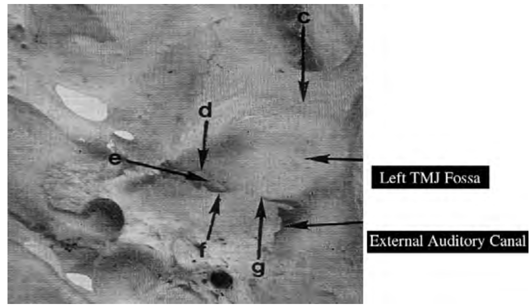

Fig. 8. Left TMJ fossa demonstrating the tympanic plate (g) anteriorly to the remnant of the articular eminence (c) of the temporal fossa and medially to the medial ridge of the fossa (d) where the medial capsule attaches superiorly to the temporal bone. e, tegmen tympani; f, a petrotympanic fissure; g, a tympanosquamosal fissure. (*Courtesy of* Bernard G. Sarnat, MD, MS, DDS, University of California, Los Angeles, CA and Daniel M. Laskin, DDS, MS, Richmond, VA; and Sarnat BG, Laskin DM, (editors). The temporomandibular joint. 3rd edition. Springfield: Charles C. Thomas; 1979; with permission.)

- The patient is placed in tight IMF at the desired occlusion using 25-gauge box wires anteriorly and posteriorly on both sides.

Component fixation

- The fossa seating tool (TMJ Concepts) is used to seat and confirm the passive positioning of this component without any movement; furthermore, this tool should be used to stabilize the implant during fixation (Fig. 9). The ramus component clamp (TMJ Concepts) is used to assist in orientation and stabilization of that component on the ramus.
- Once the fit of both components and their articulating relationship have been confirmed as correct, the fossa and ramus components are fixed using the screws with the predetermined size and length.
- The drill guide must be used when placing each screw hole into the host temporal and mandibular bones respectively. Slow drill speed and copious irrigation are necessary so as not to overheat and potentially devitalize the bone, which can lead to screw loosening. The recommended length of 2-mm diameter self-tapping bicortical screws should be placed after each hole is drilled with copious irrigation (Fig. 10).
- A percutaneous technique may be required for the most superior screw(s) in the ramus component.
- All of the screws should be placed unless the quality of the host bone prohibits and/or the 2.3-mm diameter rescue screw cannot be secured tightly. Loose screws should not be left in place.
- Once all the screws are in place, each screw should be examined to ensure that it is tight.
- In bilateral cases, the fixation protocol is repeated on the other side before closure.

Confirmation of occlusion, function, and position

- Intermaxillary fixation is released and the mandible functioned, maintaining sterility of the operative field. The joint components are directly observed to ensure proper movement with function. While the patient is in occlusion, the condylar head of the ramus component should be centered on the fossa bearing in the medial-lateral direction and seated against the fossa-bearing surface's posterior lip (TMJ Concepts) (Fig. 11).
- Training elastics may be placed for immediate postoperative comfort. Once again, care must be exercised so as not to cross-contaminate the surgical sites from the oral cavity.
- Imaging confirmation of component alignment, position, and fixation can be confirmed by obtaining an intraoperative anteroposterior skull radiograph (Fig. 12).

Fig. 9. The fossa seating tool (TMJ Concepts, Ventura, CA, USA) used to seat and confirm the passive positioning of this component without any movement and stabilize the implant during fixation.

Fig. 10. A slow-speed drill and drill guide used to prepare a screw hole into the host temporal and mandibular bones. Note the ramus component clamp (TMJ Concepts, Ventura, CA, USA) to assist in orientation and stabilization of the component on the ramus.

Fig. 11. The condylar head of the ramus component centered on the fossa-bearing surface in the medial-lateral (M/L) direction and seated against the fossa-bearing surface's posterior lip (TMJ Concepts, Ventura, CA, USA).

Fig. 12. Intraoperative anteroposterior skull imaging confirmation of component alignment, position, and fixation.

- The wounds are closed after careful and copious irrigation. Irrigation containing an antibiotic is recommended.

Postoperative auditory canal examination and pressure dressing

- The auditory canal(s) and tympanic membrane(s) should be reinspected with a speculum to ensure there was no intraoperative tear; this inspection should be documented. Any clots should be removed carefully with gentle, warm irrigation and suction.
- Ofloxacin otic drops should be instilled, and the external auditory canal(s) should be occluded with cotton.
- A Barton-type pressure dressing should be applied for a minimum of 8 to 12 hours (Fig. 13).

Fig. 13. Barton pressure dressing.

Fig. 14. When the pressure dressing is removed after 8 to 12 hours, the patient can begin using a jaw-exercising device (eg, Therabite; Atos Medical, Milwaukee, WI, USA).

Postoperative management

- Early postoperative opening should be limited to avoid dislocation, particularly in patients who have significant soft tissue laxity due to coronoidectomies or if extensive dissection was required to regain opening or reposition the mandible. The use of training elastics in the immediate postoperative period can reduce the potential for dislocation. Dislocation is typically only of concern for the first week postoperatively.
- When it is considered that the potential for dislocation is low, the training elastics can be released when the pressure dressing is removed after 8 to 12 hours, and the patient can begin using a jaw-exercising device (eg, Therabite; Atos Medical, Milwaukee, WI, USA) (Fig. 14).
- Should the patient require the assistance of a physical therapist to increase and maintain mandibular range of motion postoperatively, 2 to 3 visits per week for a minimum of 3 months is appropriate.
- One week of antibiotic therapy should follow as described earlier.
- The patient should be encouraged to chew a soft diet and advance the diet as tolerated.

Further readings

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Atlas of the Oral and Maxillofacial Surgery Clinics

Planning for Combined TMJ Arthroplasty and Orthognathic Surgery

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Temporomandibular joint (TMJ) and dentofacial deformities commonly coexist. The TMJ disorders may be the causative factor of the jaw deformity or may have developed as a result of the jaw deformity, or the 2 entities may occur independently of each other. The TMJs form the foundation for jaw position, function, occlusion, facial balance, and comfort. If the TMJs are not stable and healthy (nonpathologic), patients requiring orthognathic surgery may have unsatisfactory outcomes relative to function, aesthetics, occlusal and skeletal stability, and pain. The most common TMJ disorders that can adversely affect orthognathic treatment outcomes include (1) articular disc dislocation, (2) adolescent internal condylar resorption (AICR), (3) reactive arthritis, (4) condylar hyperplasia, (5) ankylosis, (6) congenital deformation or absence of the TMJ, (7) connective tissue and autoimmune diseases, and (8) other end-stage TMJ disorders. These TMJ conditions are often associated with dentofacial deformities, malocclusion, TMJ pain, headaches, myofascial pain, TMJ and jaw functional impairment, ear symptoms, and sleep apnea. Patients with these conditions may benefit from corrective surgical intervention, including TMJ and orthognathic surgery. The difficulty for many clinicians is in identifying the presence of a TMJ condition, diagnosing the specific TMJ disorder, and selecting the proper treatment of that condition.

Approximately 25% of patients with TMJ disorders/pathology are asymptomatic. These asymptomatic patients can be the most troublesome because the TMJ disorder may not be recognized and, thus, not treated, which results in a poor treatment outcome with potential redevelopment of the skeletal and occlusal deformity by condylar resorption or overdevelopment, as well as initiation of pain, headaches, and other TMJ symptoms.

Our research studies and those of others have clearly shown the adverse affects of performing only orthognathic surgery in the presence of displaced TMJ articular discs. With displaced discs and maxillomandibular advancement, an average anteroposterior mandibular relapse of 30% can be expected as well as an 84% chance of developing TMJ and facial pain. Proper surgical intervention for the specific TMJ disorders in orthognathic surgery patients provides highly predictable and stable results.

Patient evaluation

We have previously published detailed information on patient evaluation for orthognathic surgery, including clinical, radiographic, and dental model analyses. When the TMJs are also involved,

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additional evaluations are warranted to determine the cause, diagnoses, and treatment approach to provide optimal outcomes. It is important to know the patient's concerns and symptoms as well as treatment expectations. Subjective assessments are recorded relative to headaches, TMJ pain, myofascial pain, jaw function, diet, and disability.

History

The history includes when the patient first had any form of TMJ-related symptoms or changes in the jaw and occlusal relationship, cause, the progression of the condition, and any additional affecting factors contributing to the present circumstance. Are these symptoms static or have they become progressively worse? What previous treatments have been provided? Has the patient had previous orthognathic or TMJ surgery? Does the patient have any habitual patterns such as tongue thrust, clenching and bruxism, or thumb sucking? Are there progressive changes in the occlusion and jaw relationship? Are there other symptomatic joints in the body or major disease processes, such as connective tissue or autoimmune diseases, GI problems, recurrent urinary tract infections, diabetes, cardiac conditions, vascular compromises, airway or sleep apnea issues, smoking, alcohol or drug abuse, or female hormone imbalances? These factors may affect TMJ treatment decisions.

Clinical Examination

Orienting the head so that both the clinical Frankfort horizontal (a line from the tragus of the ear through the bony infraorbital rim area) and the pupillary and ear planes are parallel to the floor positions the head so that facial balance and the skeletal and occlusal relationships in centric relation can be assessed more easily. The patient should be evaluated for skeletal and occlusal class I, II, or III; transverse cant in the occlusal plane; high, normal, or low occlusal plane angle facial morphologic type; facial asymmetry; and dental disease.

Physical examination of the head, neck, and shoulders is performed, including palpation, to determine the presence of muscle pain and functional limitations. The TMJs are examined for incisal opening and excursion movements, pain, noises, dysfunction, and associated facial or functional asymmetries. Airway problems are common in patients with TMJ disorders; thus, airway assessment of the oral cavity, oropharyngeal area, and nasal airway is important for comprehensive treatment. Some patients may need additional evaluations, such as rheumatology, internal medicine, neurology, cardiology, sleep apnea specialists, radiology, dental specialists, or laboratory tests.

Dental Model Analyses

Dental model analysis determines the occlusal relationship and provides information for the orthodontic, surgical, and restorative dentistry protocols necessary to provide a good occlusal relationship as the end product of treatment.

Imaging

Radiographic evaluation is helpful in the diagnostic process, and cone beam technology makes low-cost, low-radiation computed tomography (CT) scans accessible. One of the best diagnostic tools for TMJ disorders is magnetic resonance imaging (MRI) because it allows evaluation of TMJ disc position, morphology, mobility, extent of joint degenerative changes, inflammation, and the presence of connective tissue/autoimmune diseases. It can help in the diagnosis of TMJ disorders in the silent joint in which disc displacement and degenerative changes can be present but may not make noise or be uncomfortable or painful, but may contribute to poor outcomes if only orthognathic surgery is performed. CT scans, bone scans, three-dimensional (3D) imaging, and 3D modeling may be beneficial for some patients. Cephalometric analysis is an important assessment for diagnosis and treatment planning (Fig. 1).

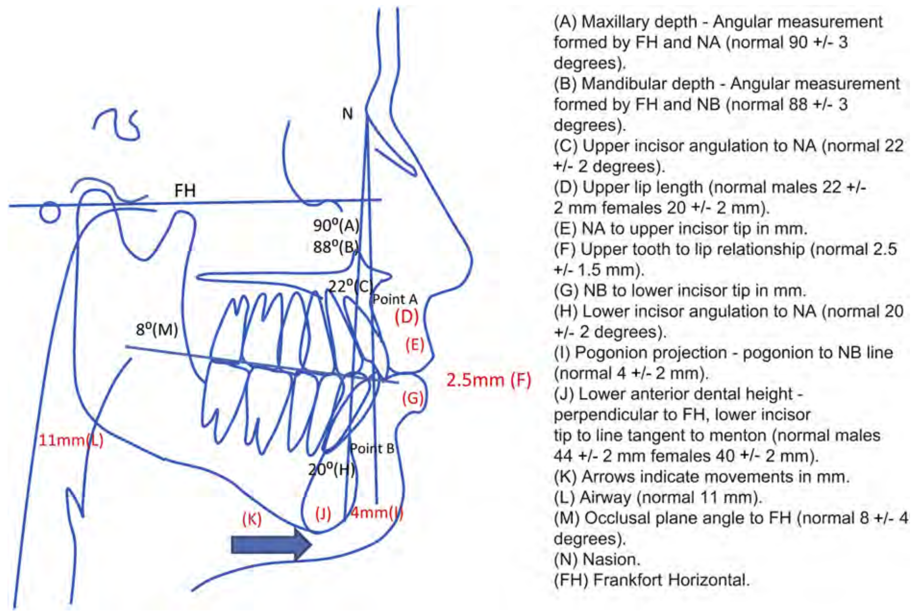

Fig. 1. Cephalometric tracing landmarks and measurements.

Comprehensive Diagnostic List and Treatment Plan

Following completion of all necessary and required evaluations, a comprehensive diagnostic list can be compiled. A definitive treatment plan can then be established to address these issues and other treatment options that may be available to allow the patient to make an informed decision as to the preferred treatment.

Gender and Age of Onset

A review of 1369 consecutive patients with TMJ disorders referred to the senior author's (LMW) practice revealed an age range of 8 to 76 years, with 78% of the patients female and 22% male. Sixty-nine percent of the patients reported the onset of their TMJ problems during the teenage years. Therefore, TMJ disorders predominantly develop in the teenage girls.

Surgical Sequencing

TMJ and orthognathic surgery can be predictably done at the same operation. Surgical sequencing includes (1) TMJ surgery; (2) mandibular ramus sagittal split osteotomies with rigid fixation; (3) maxillary osteotomies and mobilization; (4) turbinectomies and/or septoplasty, if indicated; (5) rigid fixation and bone grafting of the maxilla; and (6) adjunctive procedures, such as genioplasty, rhinoplasty, uvulopalatopharyngoplasty, or facial augmentation.

The TMJ surgery must be done first because some TMJ procedures affect the position of the mandible (ie, disc repositioning, high or low condylectomy). Mandibular sagittal split osteotomies with rigid fixation are done next so the mandible can be placed in the predetermined position regardless of the amount of displacement caused by the TMJ surgery. Also, many patients with TMJ disorders require counterclockwise rotation of the maxillomandibular complex to get the best functional and aesthetic outcomes. In this situation, it is easier to do the mandibular osteotomies before the maxillary osteotomies. If the surgeon prefers to do the TMJ surgery at a separate operation from the orthognathic surgery, then the TMJ surgery should be done first.

The Wolford modification of the sagittal split osteotomy provides an easy method to position the condyle in the fossa following TMJ surgery (Fig. 2). The primary change is that a horizontal bone cut is

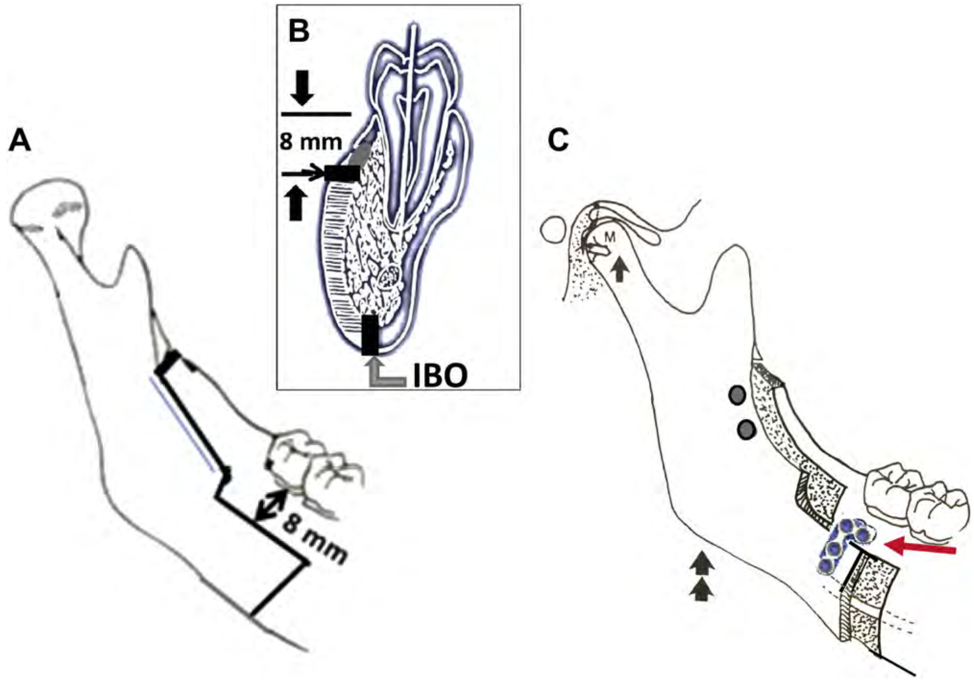

Fig. 2. (*A, B*) Wolford modification of the sagittal split osteotomy includes a horizontal cut perpendicular to the buccal cortex approximately 8 mm below the gingivocervical margin of the teeth that extends forward 8 mm further than the amount of mandibular advancement required, providing bony interface between the segments. (*B*) An inferior border osteotomy (IBO) is performed with the inferior border saw. Following segment separation and application of intermediate splint and maxillomandibular fixation, the proximal segment is seated posteriorly from intraorally and then gentle external pressure is directed upward at the angle of the mandible to seat the condyle in the fossa. (*C*) Rigid fixation is applied. Black arrows indicate direction of external digital pressure to seat condyle in fossa while bone plate is applied. Red arrow points to bony interface and bone plate.

made perpendicular to the buccal cortex (8 mm below the gingivocervical margin of the teeth) from just distal to the second molar forward 8 mm further than the amount of mandibular advancement required; as a result, there is a bony interface between the proximal and distal segments to control the position of the proximal segment and accommodate a bone plate and screws. An inferior border osteotomy is performed with a special inferior border saw and segments are separated. The mandible is repositioned with an intermediate splint and maxillomandibular fixation. The proximal segment is positioned beneath the bony ledge of the distal segment and gently pushed posteriorly at its anterior edge; gentle finger pressure is applied externally at the angle of the mandible seating the condyle into the fossa. Rigid fixation is applied, including the specially designed sagittal split bone plate and 1 to 2 screws in the anterosuperior ramus, followed by maxillary osteotomies and ancillary procedures to complete surgery.

TMJ and Facial Asymmetry

TMJ disorders are common causative factors for facial asymmetry and can produce a progressive worsening of the facial deformity and malocclusion. Unilateral condylar underdevelopment or resorption can cause the mandible and face to be smaller on one side and the jaws to shift toward the involved side. A unilateral condylar overdevelopment can also cause facial asymmetry. In this latter patient type, the normal TMJ may also develop disorders (eg, articular disc dislocation or arthritis) from the increased functional loading on that joint created by the overdevelopment of the opposite side. Performing orthognathic surgery only in facial asymmetry cases and ignoring the TMJs during treatment or failure to render proper TMJ management could result in the redevelopment of dentofacial asymmetry and malocclusion with worsening TMJ-associated symptoms, including jaw dysfunction and pain.

Number and Type of Previous Surgeries

Patients with TMJ articular disc dislocation, 0 to 1 previous TMJ surgeries, and no polyarticular conditions, may benefit from articular disc repositioning and ligament repair with Mitek anchors (Mitek Products Inc., Westwood, MA) to achieve a stable treatment outcome (Fig. 3). The success rate is highest when discs are repositioned within 4 years of initial disc displacement.

Patients with 2 or more previous TMJ surgeries have a high failure rate with disc repositioning or other autogenous tissue reconstruction. A TMJ total joint prosthesis, such as the TMJ Concepts Inc. system (Ventura, CA), have a much higher rate of success (Fig. 4). Patients with TMJ involvement of connective tissue and autoimmune diseases may benefit from total joint prosthesis reconstruction because the disease processes will likely attack any autogenous tissues placed in the joint area, but will not affect the total joint prostheses. Other end-stage TMJ conditions, such as severe reactive arthritis or osteoarthritis, ankylosis, severe damage from trauma, failed TMJ alloplastic implants, or polyarticular conditions, will get the most predictable results with total joint prostheses and fat grafts packed around the articulating components of the prostheses.

Age for Surgical Intervention

Predictability of results and limiting correction of the jaw and TMJ-related deformities to 1 major operation can best be achieved by waiting until growth is nearly complete. Although there are individual variations, girls usually have most of their facial growth (98%) complete by the age of 15 years and boys by the age of 17 to 18 years. Performing surgery at earlier ages may result in the need for additional surgery at a later time to correct a resultant deformity and malocclusion that may develop during the completion of growth. There are definite indications for early surgery, such as progressive TMJ deterioration, ankylosis, growth center transplants (ie, rib or sternoclavicular grafts), masticatory dysfunction, tumor removal, pain, and sleep apnea. We have previously published studies on maxillary and mandibular surgery and their effects on growth with guidelines for age when considering surgical intervention.

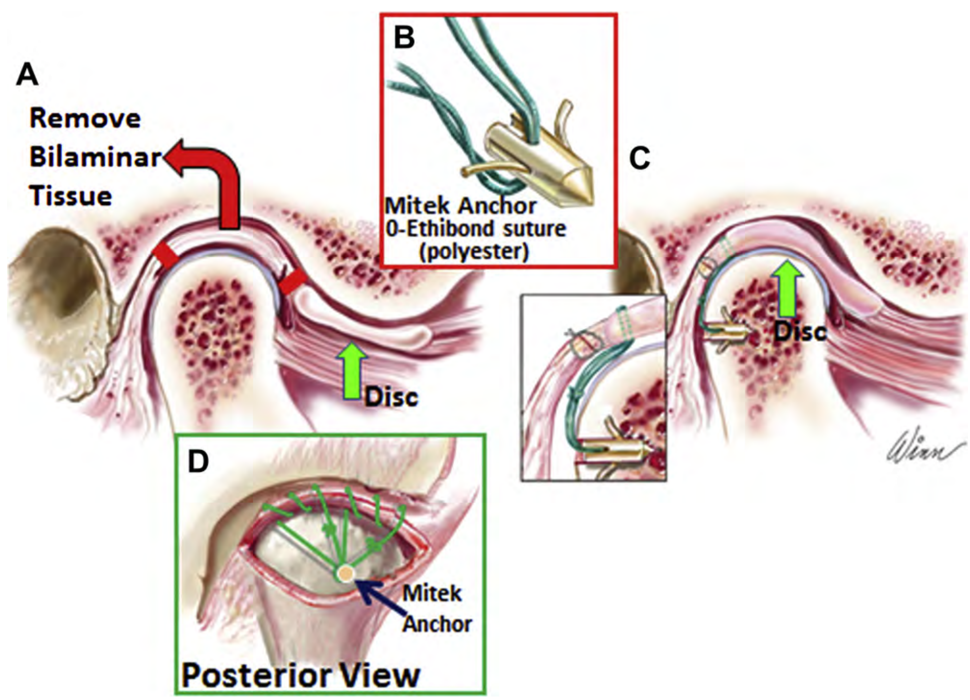

Fig. 3. (*A*) The excessive bilaminar tissue is excised, and the disc is mobilized and repositioned. (*B*) Two 0-Ethibond sutures are passed through the eyelet of a Mitek mini anchor using the included threading device. (*C*) The anchor is placed into the posterior head 8 mm below the crown of the condyle just lateral to the midsagittal plane. (*D*) The sutures are attached to the posterior aspect of the posterior band with 3 over-and-over sutures for each set of artificial ligaments; 1 set placed medial and 1 placed more lateral.

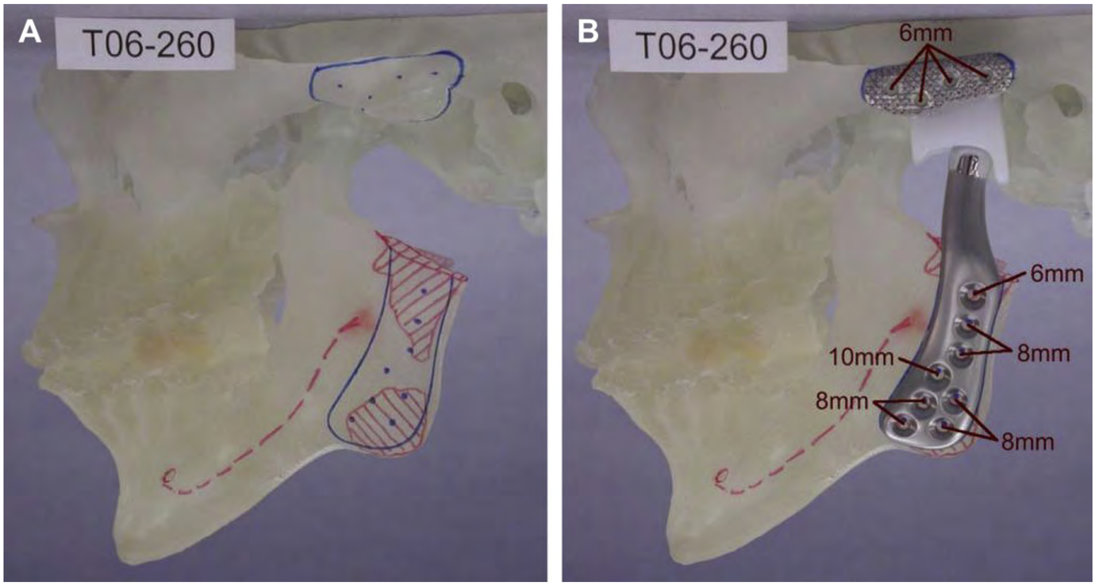

Fig. 4. (*A*) The TMJ Concepts total joint prosthesis is a patient-fitted device designed for the patient's specific anatomic requirements based on construction of a three-dimensional stereolithic model. Dashed line represents inferior alveolar nerve canal. Shaded areas designate bony recontouring of the ramus to facilitate design and manufacture of the total joint prosthesis. (*B*) Design of the prostheses can include large counterclockwise rotations of the maxillomandibular complex if indicated. Numerical values indicate screw length to penetrate through the lingual cortex.

Nonsurgical and Closed Treatment Considerations

Nonsurgical TMJ treatments (eg, splints, physical therapy, chiropractic treatment, orthodontics, biofeedback, acupuncture, and medications) may help the TMJ symptoms but do not stabilize and eliminate TMJ disorders (eg, disc dislocation, arthritis, condylar resorption, or condylar hyperplasia) to withstand the increased TMJ loading that usually accompanies orthognathic surgery. Arthrocentesis and arthroscopy are contraindicated in patients with TMJ disorders requiring orthognathic surgery because these techniques do not reposition and stabilize the articular disc in a normal position, but may convert a reducing disc into a nonreducing disc that will yield a more rapid deformation and degeneration process of the disc, subsequently rendering it nonsalvageable.

Condylar overdevelopment conditions

Condylar Hyperplasia Type 1

Patients with condylar hyperplasia (CH) type 1 may have a class I occlusion at the beginning of puberty and develop into a class III, or begin as a class III but develop a worse class III relationship with accelerated mandibular growth that can continue into the mid-20s, although it is eventually self-limiting. Bilateral active CH type 1 causes progressive worsening prognathism and occlusion but usually asymptomatic TMJs. Unilateral or bilateral CH type 1 with asymmetric growth can cause progressive deviated prognathism, facial asymmetry, disc dislocations, TMJ pain, headaches, and masticatory dysfunction (Figs. 5A–D, 6A). Not all prognathic mandibles are caused by CH; only those showing accelerated, excessive mandibular growth continuing beyond the normal growth years. MRI may show thin discs that sometimes are difficult to identify; they tend to have vertically long, but otherwise normally shaped, condyles, and disc displacements are more commonly seen in deviated prognathism. Posterior disc displacements occasionally occur.

Our treatment protocol for patients with active CH type 1 includes (1) high condylectomy to arrest the mandibular growth; (2) TMJ disc repositioning over the top of the condyle with a Mitek anchor (see Fig. 6C, D); (3) bilateral mandibular ramus osteotomies; and (4) maxillary osteotomies and

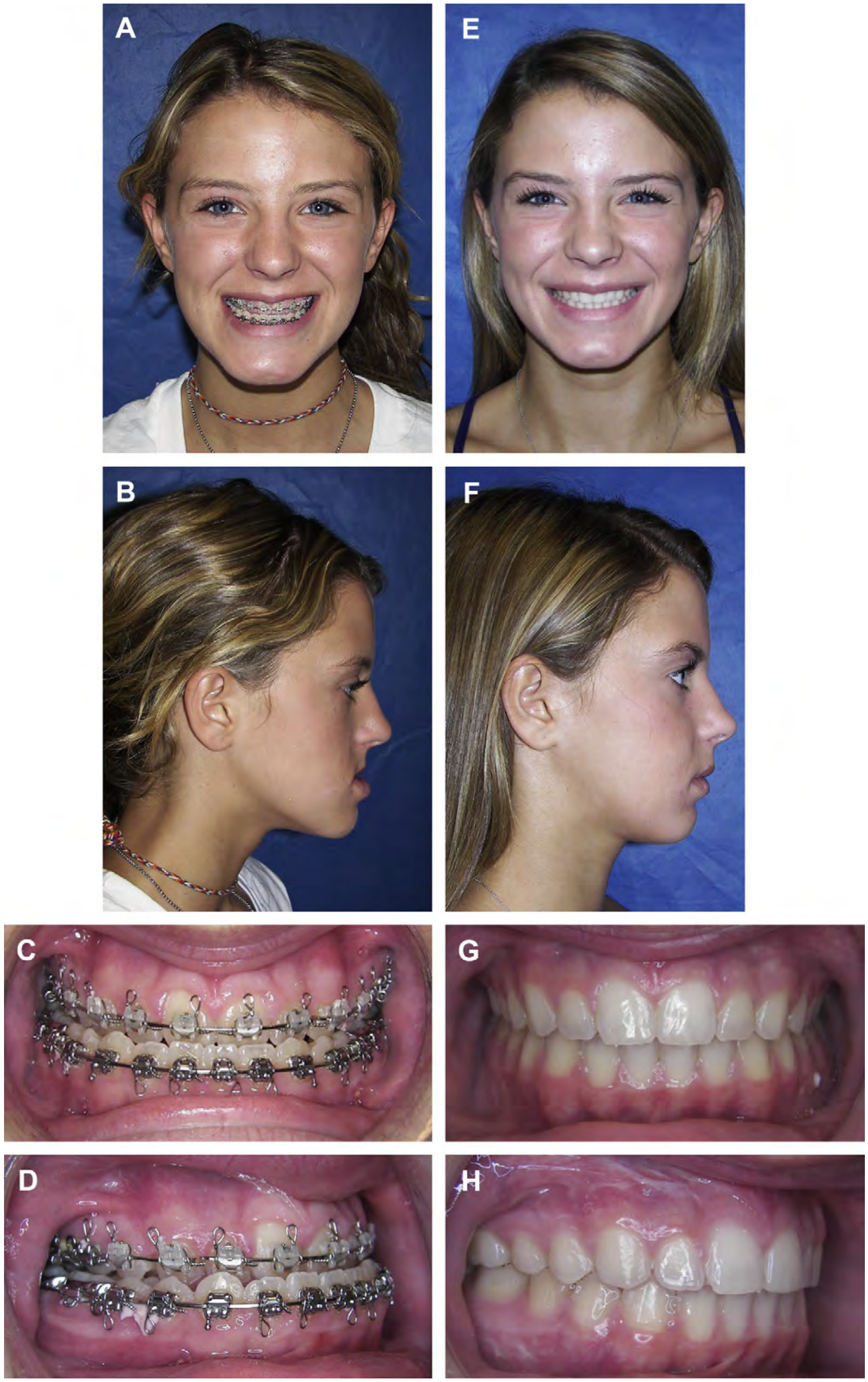

Fig. 5. Case 1. (*A–D*) A 14-year-old girl with (1) CH type 1, onset age 11 years, greater growth on the left side and right disc anterior dislocation; (2) mandibular deviated prognathism; (3) maxillary hypoplasia; (4) class III occlusion, greater on the left; (5) impacted third molars; and (6) TMJ pain and headaches. Single-stage surgery included (1) bilateral TMJ high condylectomies with disc repositioning using Mitek anchors; (2) mandibular ramus osteotomies to correct the asymmetry, set mandible posteriorly, and decrease the occlusal plane angle; (3) maxillary osteotomies to advance and expand; and (4) removal of third molars $\times 4$. (*E–H*) At 2.5 years after surgery, the patient was pain free with good facial balance, occlusion, and airways, and mandibular condylar growth was eliminated.

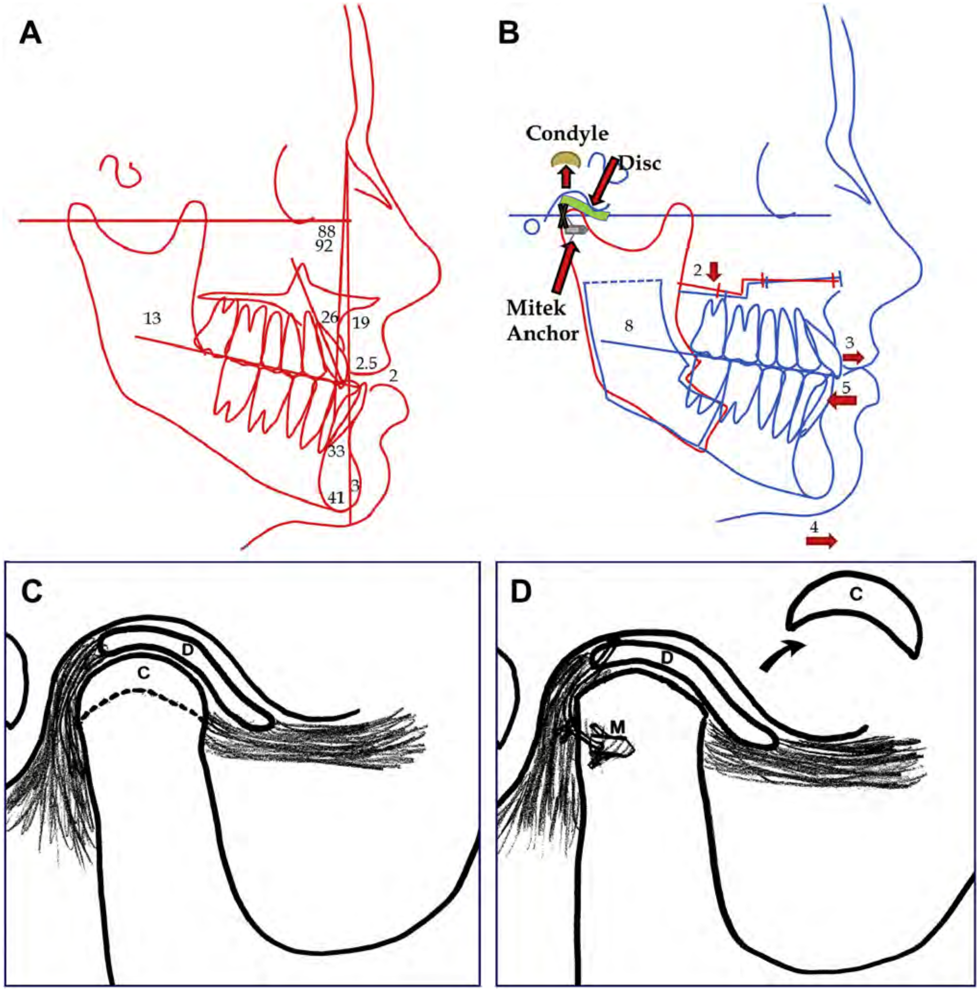

Fig. 6. Case 1. (*A*) Cephalometric analysis shows the class III skeletal and occlusal relationship, mandibular prognathism, and maxillary hypoplasia. (*B*) Prediction tracing shows high condylectomies, repositioning the articular discs with Mitek anchors, mandibular repositioning, and maxillary advancement. (*C*, *D*) The high condylectomy (C) and repositioning of the disc (D) with a Mitek (M) anchor.

adjunctive procedures if indicated (see Figs. 5E–H; 6B). Our studies show that this protocol stops mandibular growth and provides highly predictable and stable skeletal and occlusal outcomes with normal jaw function and good aesthetics. Treating active CH type 1 with orthodontics and/or orthognathic surgery only, without including the high condylectomy, results in a high relapse rate with redevelopment of a class III skeletal and occlusal relationship.

CH Type 2; Osteochondroma or Osteoma

CH type 2 is a unilateral overdevelopment (enlargement) of the condyle that is usually caused by a benign tumor (osteochondroma or osteoma). CH type 2 usually causes unilateral progressive vertical elongation of the mandible and compensatory downgrowth of the maxilla, a potential posterior open bite on the ipsilateral side, and a transverse cant in the occlusal plan (Figs. 7A–D, 8A). CH type 2 can occur at any age and can usually be identified radiographically by an enlarged deformed condyle that often has exophytic growth, a wide condylar neck, and increased vertical height of the mandible on the involved side. MRI commonly shows an ipsilateral, enlarged, deformed condyle with the disc in position, but the contralateral side may have a displaced disc and arthritic changes from the functional overload.

Our treatment protocol for this TMJ disorder includes (1) low condylectomy preserving the condylar neck, (2) recontouring the condylar neck to function as a new condyle, (3) repositioning the

Fig. 7. Case 2. (*A–D*) A 45-year-old woman with (1) right-side CH type 2 (osteochondroma), onset at age 18 years, with progressive worsening facial asymmetry; (2) left TMJ arthritis and disc dislocation; (3) right mandibular and maxillary vertical hyperplasia and asymmetry; (4) transverse cant in the occlusal plane; (5) chin midline shifted 13 mm to the left; and (6) severe TMJ pain, headaches, and myofascial pain. (*E–H*) Single-stage surgery included (1) right mandibular low condylectomy; (2) bilateral TMJ disc repositioning with Mitek anchors; (3) bilateral ramus osteotomies to shift the mandible back to the facial midline and level transversely; (4) multiple maxillary osteotomies for alignment; (5) right inferior border ostectomy; and (6) genioplasty.

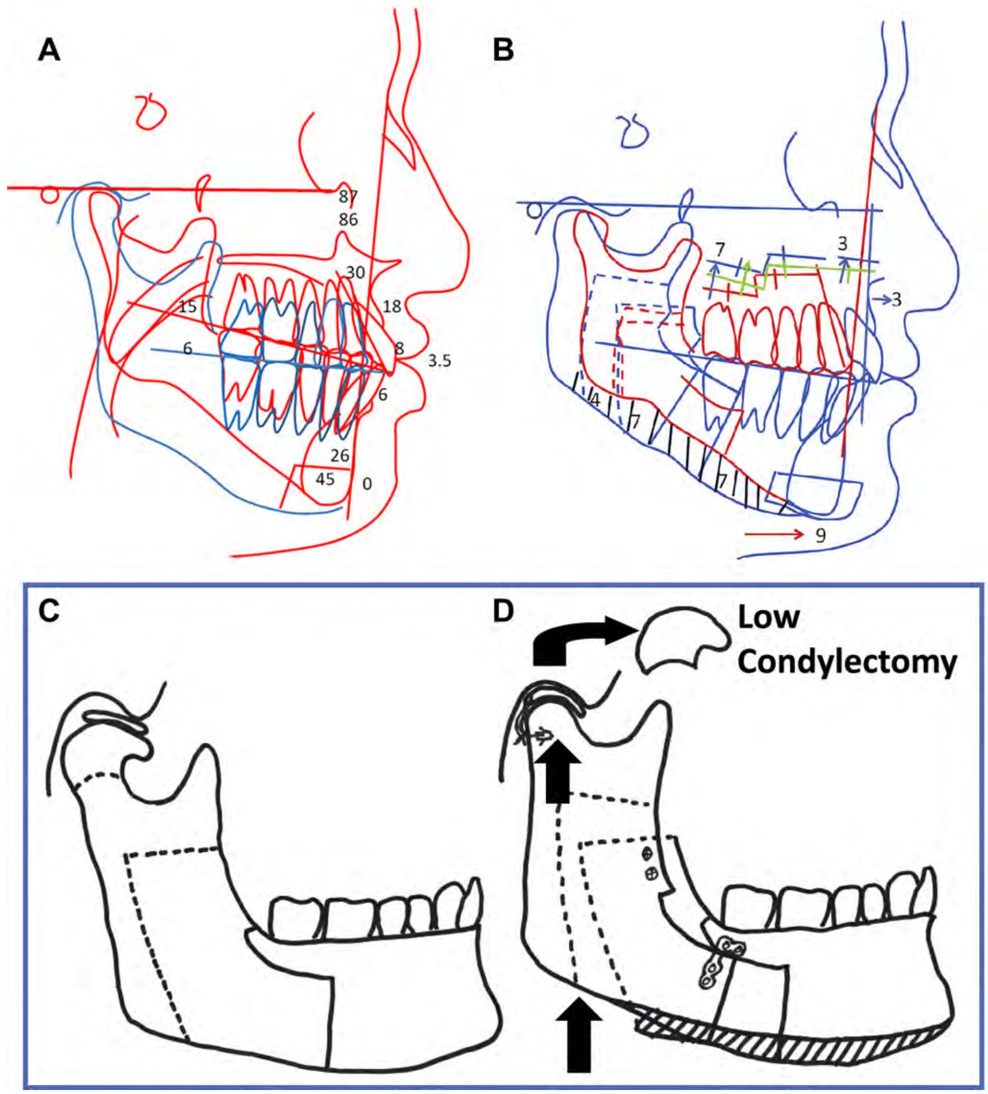

Fig. 8. Case 2. (*A*) Cephalometric tracing shows the vertical difference between the elongated mandibular right side and at the occlusal plane. (*B*) Prediction tracing shows right low condylectomy and bilateral disc repositioning with a Mitek anchor, double jaw orthognathic surgery, genioplasty, and ostectomy of right inferior border. (*C*) Commonly, but not always, osteochondromas have exophytic growths extending from the condylar head. (*D*) Indicated surgery includes a right low condylectomy, disc repositioning, double jaw orthognathic surgery, and right inferior border ostectomy.

articular disc over the condylar stump and contralateral condyle, (4) orthognathic surgery usually including both jaws, and (5) vertical reduction of the inferior border of the mandible on the ipsilateral side if indicated to improve vertical facial balance (see Figs. 7E–H; 8B–D). Our studies have shown that this technique predictably eliminates the TMJ disorder and maintains long-term skeletal and occlusal stability and facial balance.

Condylar underdevelopment/resorption conditions

Articular Disc Dislocation

The most common TMJ disorder associated with dentofacial deformity is an anterior and/or medially displaced disc. This condition can initiate a cascade of events leading to arthritis and TMJ-related symptoms (Figs. 9A–D, 10A). MRI shows anterior disc displacement, degeneration, and hypomobility of joint components (see Fig. 10C, D). Simultaneous surgical treatment could include

Fig. 9. Case 3. (*A–D*) A 42-year-old woman with (1) bilateral TMJ arthritis and anteriorly displaced discs; (2) maxillary and mandibular hypoplasia; (3) high occlusal plane angle; (4) hypertrophied turbinates with nasal airway obstruction; (5) decreased oropharyngeal airway (ie, sleep apnea); and (6) myofascial pain. Single-stage surgery included (1) bilateral TMJ disc repositioning with Mitek anchors; (2) bilateral mandibular ramus and maxillary osteotomies to advance forward in a counterclockwise direction, and genioplasty with pogonion advancing a total of 19 mm; and (3) bilateral partial turbinectomies. (*E–H*) The patient was seen 9 years after surgery pain free and with a stable result.

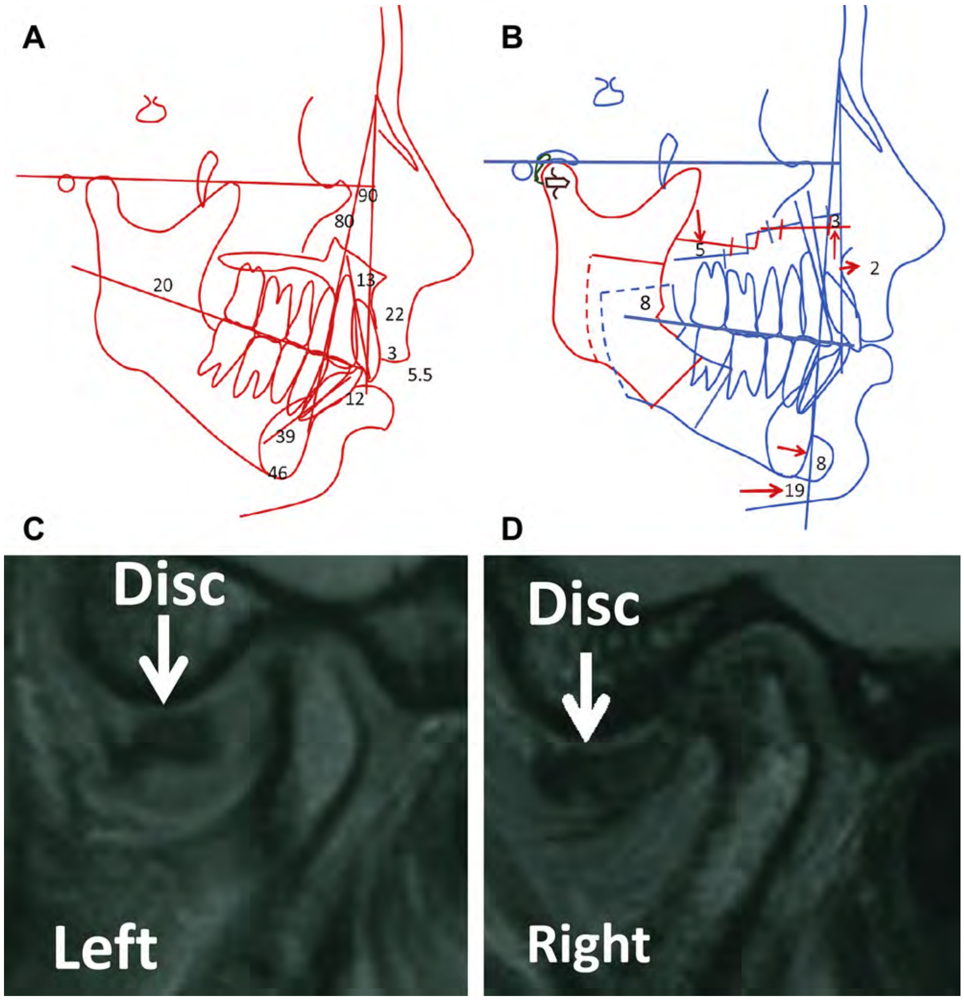

Fig. 10. Case 3. (*A*) Presurgical cephalometric tracing illustrates the retruded maxilla and mandible and high occlusal plane angle facial morphology. (*B*) The prediction tracing illustrates the planned surgical procedures with TMJ disc repositioning with Mitek anchors, osteotomies for counterclockwise rotation of the maxillomandibular complex, and genioplasty. (*C, D*) MRI shows arthritic changes as well as anteriorly displaced articular discs.

repositioning the TMJ disc into a normal anatomic, functional position and stabilizing it using the Mitek anchor technique (see Fig. 3). Two 0-Ethibond sutures (Ethicon Inc., Somerville, NJ, USA) are threaded through the Mitek anchor islet, and the anchor is placed into the posterior head of the condyle lateral to the midsagittal plane. The sutures are used as artificial ligaments to secure and stabilize the disc to the condylar head. The indicated orthognathic surgery is then performed (see Figs. 9E–H; 10B).

In our studies using the criteria of incisal opening greater than 35 mm, stable skeletal and occlusal relationships, and significant reduction in pain, the success rate was 91%. The success rate was significantly better (95%) if the TMJ discs were surgically repositioned within the first 4 years of the onset of TMJ dysfunction. After 4 years, the progression of irreversible TMJ degenerative changes may result in a lower success rate. Significant degeneration of the TMJ may require total joint prostheses (see Fig. 4).

In patients with good facial balance, class I occlusion, but anteriorly displaced articular discs, repositioning the discs usually creates a malocclusion with end-on incisors as well as class III occlusion and posterior open bites. In this situation, bilateral mandibular ramus sagittal split osteotomies performed at the same operation maintain the original occlusion and create space between the condyle and fossa to accommodate the repositioned disc.

AICR

AICR is one of the most common TMJ conditions seen in teenage girls (8:1, female/male). This hormonally mediated condition is initiated as the adolescent enters the pubertal growth phase (age of onset 11–15 years). The discs become anteriorly displaced and the condylar heads resorb with slow but progressive retrusion of the mandible, which creates a class II occlusal relation and an anterior open bite. Twenty-five percent of patients with AICR are asymptomatic relative to pain and joint noises but still have the displaced discs and condylar resorption. All patients have high occlusal plane angulation with a retruded mandibular facial morphology (Figs. 11A–D, 12A). MRI shows anteriorly displaced discs, small condyles, and amorphous tissue surrounding the condyles (see Fig. 12C). When the discs are still salvageable, our treatment protocol has proved to eliminate this TMJ disorder and to allow optimal correction of the associated dentofacial deformity at the same operation. The protocol includes (1) removing the tissue surrounding the condyle, (2) repositioning and stabilizing the disc to the condyle with a Mitek anchor and artificial ligaments (see Fig. 3), and (3) performing the indicated double jaw orthognathic surgery and adjunctive procedures (see Figs. 11E–H; 12B).

Our studies and others have shown that performing only orthognathic surgery on patients with AICR results in predictable continued condylar resorption with subsequent skeletal relapse, redevelopment of a class II anterior open bite, and increased pain. Our protocol eliminates this TMJ disorder and produces stable class I occlusal outcomes with elimination of pain, improved jaw function, and good facial balance. In advanced AICR disorders with nonsalvageable discs, total joint prostheses (see Fig. 4) with fat grafts may be indicated to reconstruct the TMJs and advance the mandible.

Reactive Arthritis

Reactive arthritis (also called seronegative spondyloarthropathy) is an inflammatory process that commonly occurs in TMJs with displaced discs, with or without condylar resorption (Figs. 13A–D, 14A) and is usually related to bacterial and/or viral disorders. This condition is most commonly seen in women and does not usually begin until the late teenage years or later. Our studies have identified bacteria species from the *Chlamydia* and *Mycoplasma* genera. These bacteria live and function like viruses and stimulate the production of substance P, cytokines, and tissue necrosis factor, which are pain modulators. We suspect that other bacterial and viral elements could also be causative factors. MRI may show displaced disc, inflammation, and progression of disc and condylar degeneration (see Fig. 14C). Patients with localized TMJ reactive arthritis and displaced discs may respond well to joint debridement and disc repositioning with the Mitek anchor technique (see Fig. 3) and the appropriate orthognathic procedures to correct a coexisting dentofacial deformity (see Figs. 13E–H; 14B). In more aggressive forms of the disease or polyarthropathy, total joint prostheses (see Fig. 4) with fat grafts may be indicated.

Trauma

Traumatic injuries to the jaws may develop facial deformities, particularly those that involve the TMJs with unilateral or bilateral condylar or subcondylar fractures that are inadequately reduced. Patients may present with (1) mandible retruded or deviated toward the affected side, if unilateral; (2) pain and jaw dysfunction; (3) deficient growth on the affected side(s) in growing patients; (4) class II skeletal and occlusal relationships; and (5) premature contact of the occlusion on the affected side(s) and open bite (Figs. 15A–D, 16A). Imaging features could include (1) evidence of previous condylar, mandibular, or midfacial fractures; (2) the condyle, when fractured, may be malpositioned downward, forward, and medial to the fossa; and (3) decreased vertical ramus/condyle length (see Fig. 16C). MRI also shows the disc position and condition.

At the initial presentation of the trauma, the options for treating subcondylar fractures are open reduction, closed reduction, or no treatment. The amount of displacement and the condition of the fracture(s) affect the treatment needed to fix the problem. When identified early, fractures may be

Fig. 11. Case 4. (*A–D*) A 15-year-old girl with (1) bilateral TMJ AICR, onset at age 12 years; (2) retruded maxilla and mandible with high occlusal plane angle facial morphology; (3) class II open bite; (4) hypertrophied turbinates; (5) adenoid hyperplasia; and (6) sleep apnea symptoms. Single-stage surgery included (1) bilateral TMJ disc repositioning with Mitek anchors; (2) maxillary and mandibular osteotomies to counterclockwise rotate the maxilla and mandible forward and an osseous genioplasty with pogonion advancing a total of 18 mm; (3) bilateral partial turbinectomies; and (4) adenoidectomy. (*E–H*) The patient was seen 18 months after surgery with good functional and aesthetic stability.

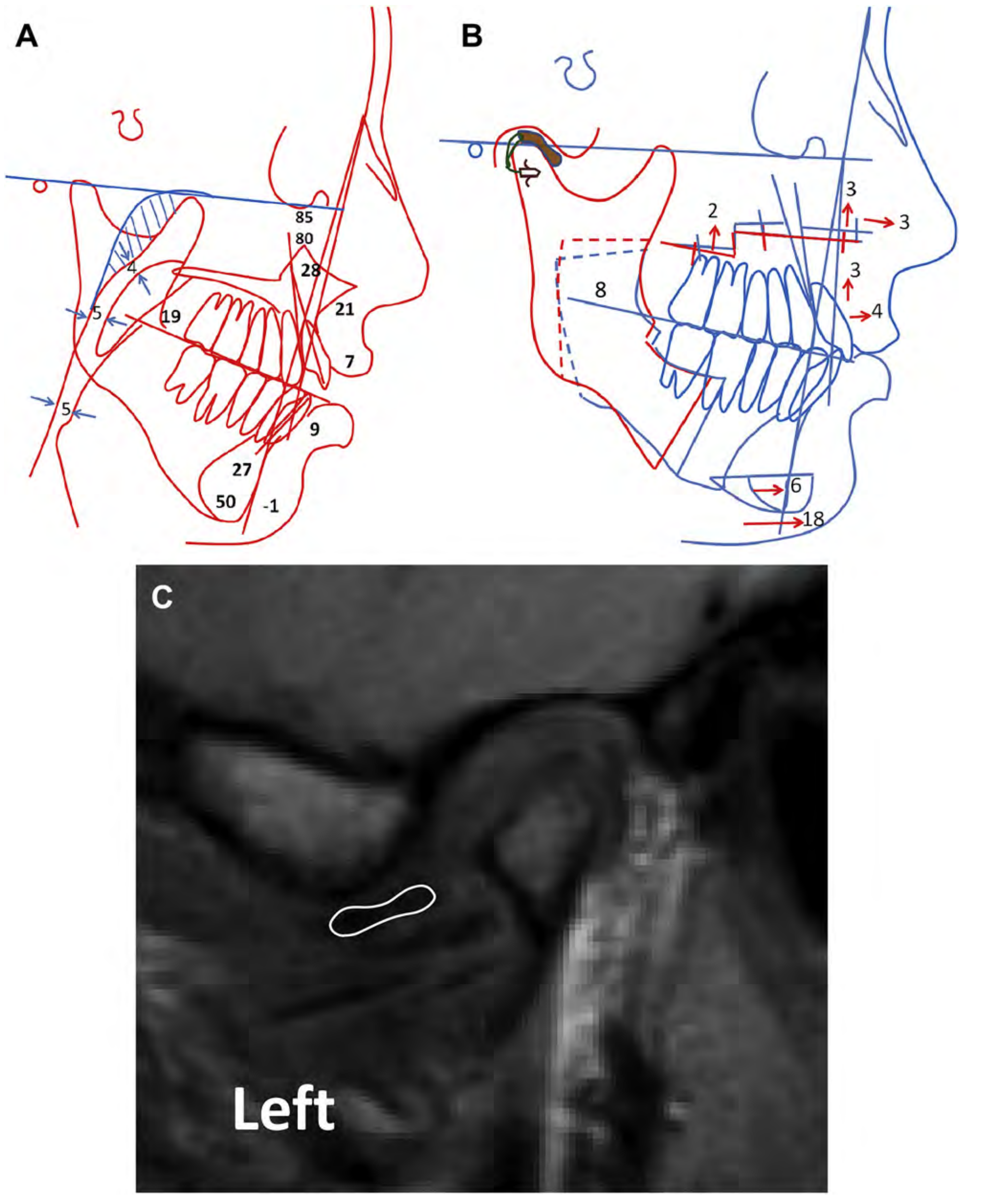

Fig. 12. Case 4. (*A*) Cephalometric analysis shows the retruded maxilla and mandible with the high occlusal plane angle facial morphology that accompanies AICR, anterior open bite, and hyperplastic adenoid tissue. (*B*) The prediction tracing shows the disc repositioning with Mitek anchors, counterclockwise rotation of the maxillomandibular complex with genioplasty where pogonion was advanced 18 mm, adenoidectomy, and closure of the anterior open bite. (*C*) MRI shows condylar resorption and articular disc dislocation, compatible with AICR.

best treated by open reduction for significantly displaced segments or closed reduction for minimally displaced segments to achieve a symmetric face and stable occlusion. If the condyle is minimally to moderately displaced, still salvageable along with its articular disc but already healed, then it is possible that orthognathic surgery could realign the jaw structures properly, and, if the disc is displaced, it can be repositioned with a Mitek anchor (see Fig. 3). If the condyle is severely deformed and nonsalvageable, then the most predictable reconstruction of the TMJ and repositioning of the mandible is using patient-fitted total joint prostheses (TMJ Concepts system, Fig. 4) and fat grafts (see Figs. 15E–H; 16B). Other treatment options for TMJ reconstruction include rib grafts and sternoclavicular grafts.

Fig. 13. Case 5. (*A–D*) A 41-year-old man had double jaw orthognathic surgery 10 years earlier but slowly developed facial asymmetry, right TMJ pain, and headaches. His maxilla and mandible were retruded and asymmetric. He was diagnosed with right TMJ reactive arthritis (bacteria: *Chlamydia psittaci*) with condylar resorption and disc dislocation. Single-stage surgery included (1) right TMJ articular disc repositioning with Mitek anchor; and (2) maxillary and mandible osteotomies to vertically lengthen the right side of the jaws and advance in a counterclockwise direction. (*E–H*) At 8 years after surgery, the patient was pain free and maintained good facial symmetry and occlusion.

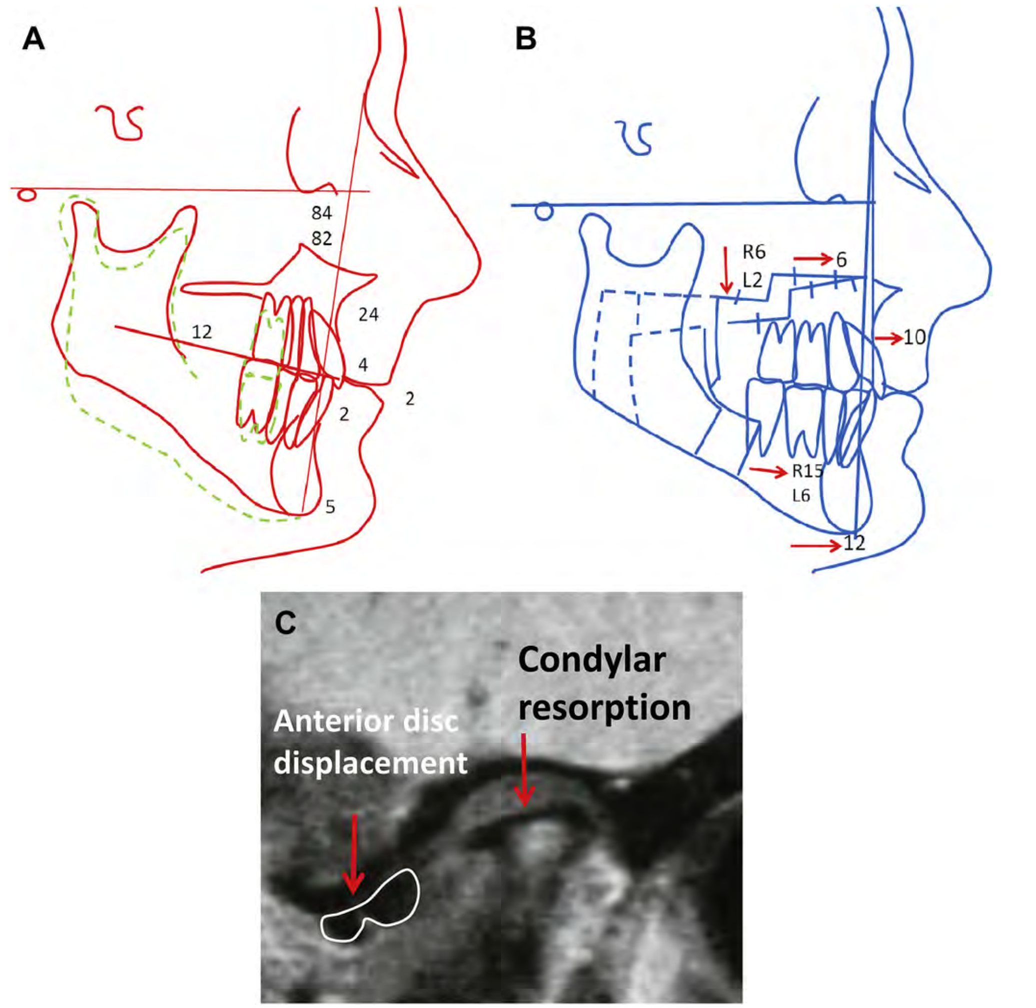

Fig. 14. Case 5. (*A*) Cephalometric analysis shows the vertical difference between the inferior border and the occlusal plane as well as the retruded maxilla and mandible. (*B*) Prediction tracing shows the planned surgery to reposition the right TMJ articular disc, and advance and level the maxilla and mandible. (*C*) MRI shows condylar resorption and the anteriorly displaced disc in the right TMJ.

TMJ ankylosis

TMJ bony ankylosis usually develops as a result of trauma, inflammation, sepsis, and/or systemic diseases that cause severely limited jaw function, as well as oral hygiene and nutritional problems. When this condition occurs during the growing years, it can severely affect jaw growth and development. In unilateral ankylosis, the other condyle continues to grow but may be retarded in its true growth potential. The common clinical and radiographic characteristics of TMJ ankylosis, particularly when occurring in children, include decreased jaw mobility and function, decreased growth on the involved side, facial asymmetry if unilateral involvement with the mandible shifted toward the ipsilateral side, retruded mandible, a class II occlusion (Figs. 17A–D, 18A), and radiographic and MRI evidence of bony ankylosis between the condyle and the fossa or heterotopic bone surrounding the joint.

The most predictable treatment of the patient with ankylosed TMJ includes (1) releasing the ankylosed joint, (2) removing the heterotopic and reactive bone with thorough debridement of the TMJ and adjacent areas, (3) reconstructing the TMJs (and, if indicated, advance the mandible) with a patient-fitted total joint prosthesis (TMJ Concepts System, Fig. 4), (4) coronoidotomies or

Fig. 15. Case 6. (*A–D*) A 52-year-old woman sustained multiple mandibular fractures including bilateral subcondylar fractures 4 years earlier. She had (1) severely retruded mandible with high occlusal plane angle; (2) class II occlusion with anterior open bite; (3) posterior cross bite; (4) severe pain; and (5) sleep apnea. Single-stage surgery included (1) bilateral TMJ reconstruction and mandibular counterclockwise advancement with TMJ Concepts total joint prostheses with pogonion advancing 28 mm; (2) left mandibular body osteotomy; (3) multiple maxillary osteotomies; (4) fat grafts placed around the TMJ prostheses; and (5) coronoidectomies. (*E–H*) At 6 years after surgery, the patient had good facial balance and occlusion with significant reduction in pain and elimination of sleep apnea.

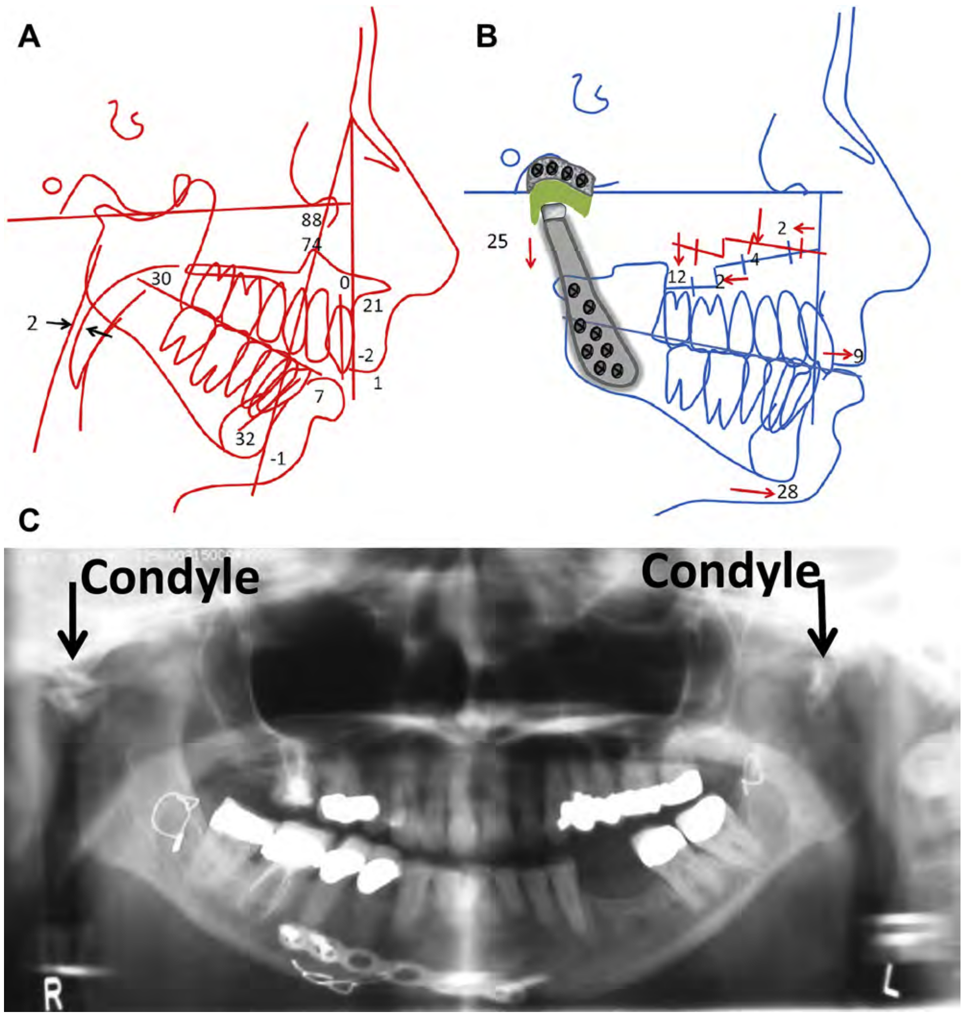

Fig. 16. Case 6. (*A*) Cephalometric tracing shows severely retruded mandible and high occlusal plane angle, class II open bite, and severely decreased oropharyngeal airway. (*B*) Prediction tracing shows bilateral TMJ reconstruction and mandibular counterclockwise rotation using TMJ Concepts total joint prostheses with pogonion advancing 28 mm, and maxillary osteotomies. (*C*) The displaced subcondylar fractures are seen on the presurgery radiograph.

coronoidectomies if the ramus is significantly advanced or vertically lengthened with the prostheses, (5) packing an autogenous fat graft (harvested from the abdomen or buttock) around the prosthesis in the TMJ area, and (6) additional orthognathic surgery if indicated (see Figs. 17E–H; 18B). In these cases, it is necessary for the fat grafts to be packed around the articulating parts of the prosthesis to prevent the reoccurrence of heterotopic and reactive bone as well as to minimize fibrosis.

Other techniques that have been advocated for reconstruction of TMJ ankylosis include using autogenous tissues, such as temporal fascia and muscle flaps, dermis-fat grafts, rib grafts, sternoclavicular grafts, and vertical sliding osteotomy. The total joint prosthesis with a fat graft packed around it is a superior technique in terms of preventing reankylosis, jaw and occlusion stability, improving function and facial balance, and eliminating or decreasing pain. When treating young, growing patients (10 years or older), the patient-fitted total joint prosthesis may still be the best option to eliminate the ankylosis. However, because there is no growth potential on the ipsilateral side of the mandible (there is also no growth potential with a bony ankylosis), orthognathic surgery will likely be necessary but can be delayed until the patient has completed most facial growth (girls, age 15 years; boys, age 17–18 years). Double jaw orthognathic surgery can then be performed, including a ramus sagittal split on the side of the prosthesis to reposition the jaws into the best

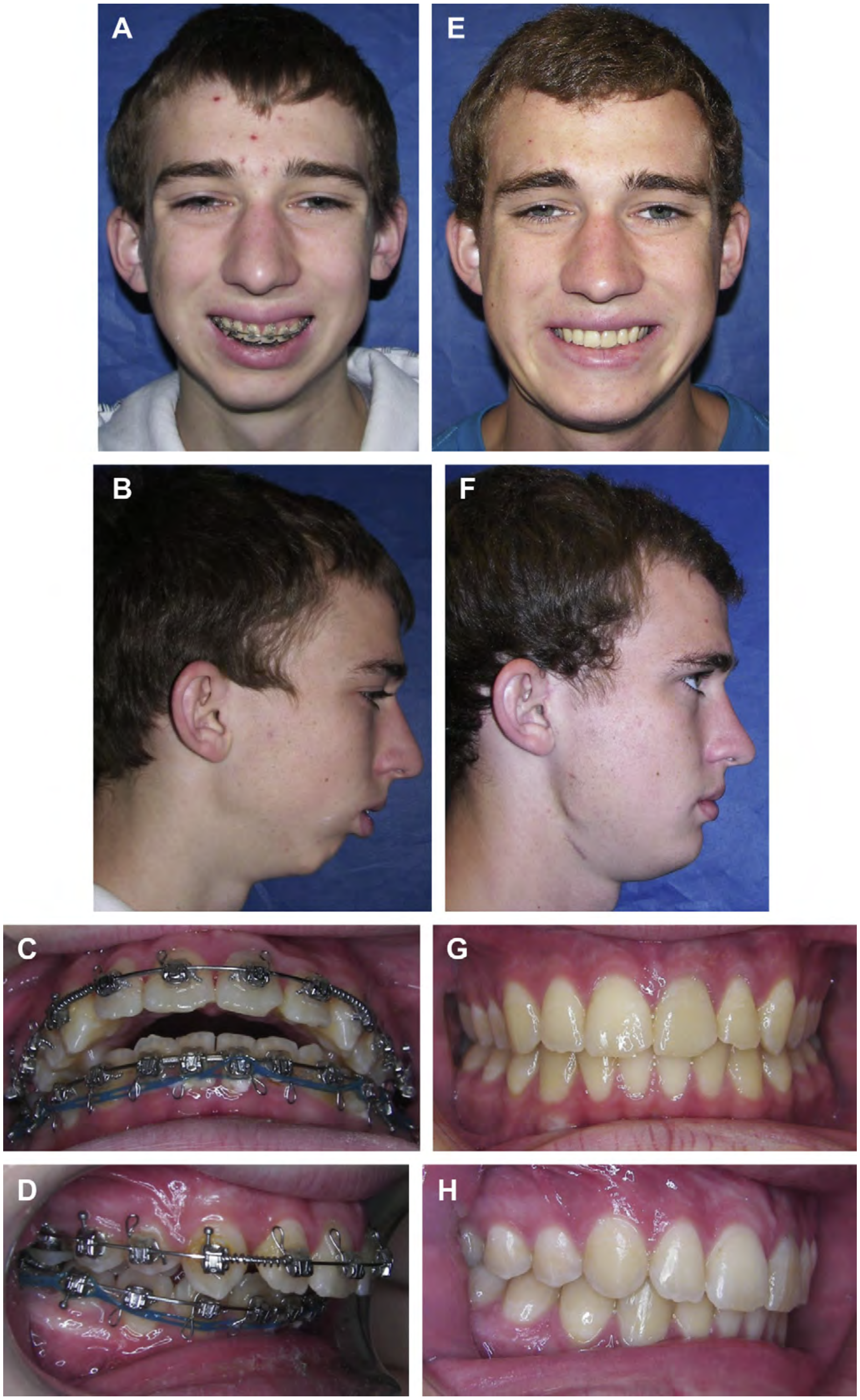

Fig. 17. Case 7. (*A–D*) A 15-year-old boy sustained mandibular trauma at age 8 years, resulting in (1) right TMJ bony ankylosis and left TMJ fibrous ankylosis; (2) retruded mandible and maxilla with high occlusal plane angle facial morphology; (3) hypertrophied turbinates, adenoids, and tonsils; (4) impacted third molars; and (5) sleep apnea. Single-stage surgery included (1) bilateral TMJ reconstruction and mandibular counterclockwise advancement with TMJ Concepts total joint prostheses and chin implant with pogonion advancing a total of 20 mm; (2) maxillary osteotomies; (3) turbinectomies, tonsillectomies, and adenoidectomy; and (4) removal of third molars. (*E–H*) The patient was seen 2 years after surgery, pain free and with good stability, function, and facial balance, and an incisal opening of 54 mm.

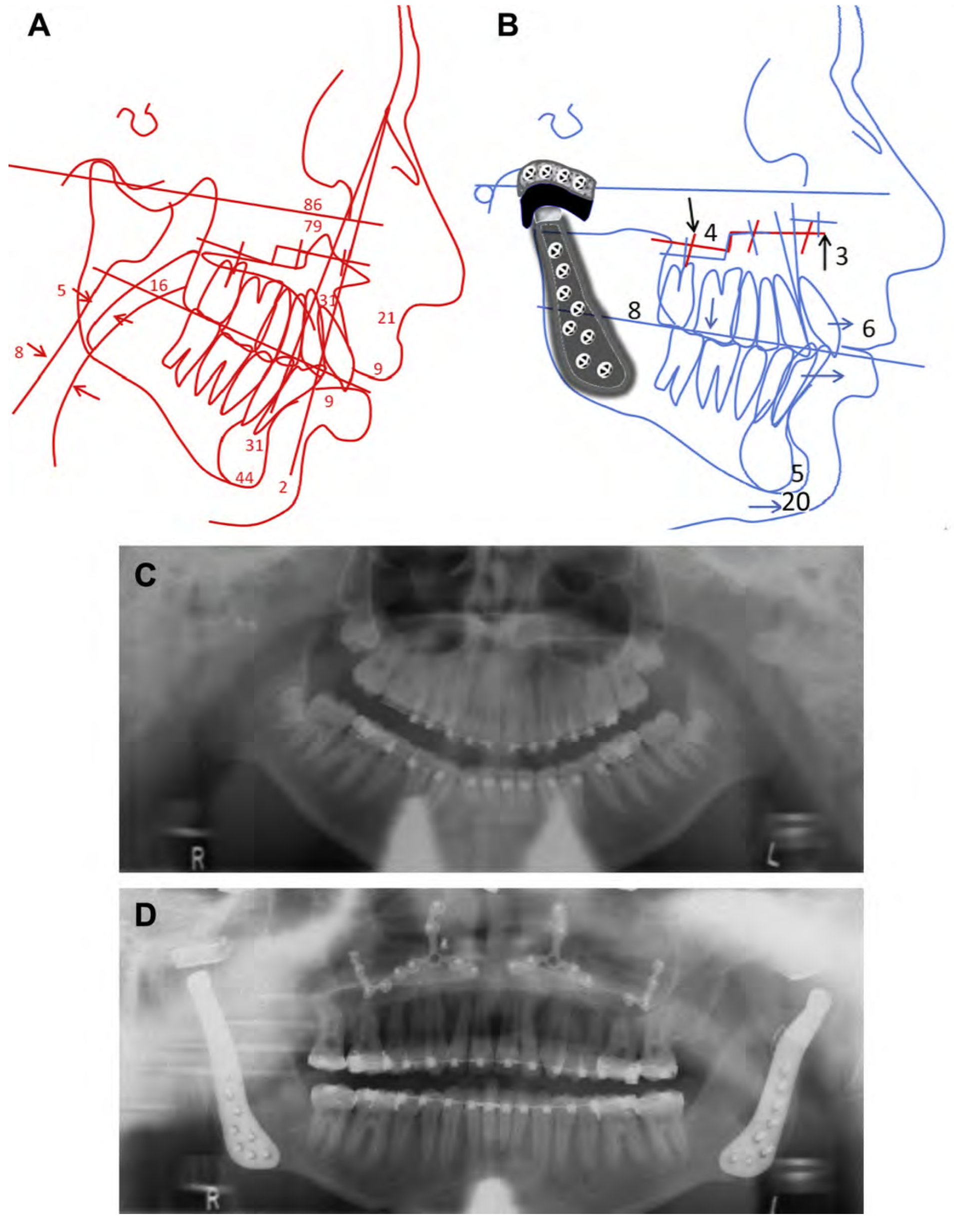

Fig. 18. Case 7. (*A*) Cephalometric tracing shows the retruded maxilla and mandible with high occlusal plane angle. The oropharyngeal airway is significantly decreased, hyperplastic adenoid tissue is present, and a class II occlusion is also present. (*B*) Prediction tracing shows the advancement of the maxillary and mandibular complex in a counterclockwise direction using TMJ Concepts total joint prostheses to reconstruct the TMJs and mandible and genioplasty with pogonion advancing a total of 20 mm. Presurgery (*C*) and postsurgery (*D*) radiographs show the prostheses and bone plates securing the maxilla.

alignment, or the ipsilateral side can be advanced by repositioning the mandibular component of the prosthesis or fabrication of a new, longer mandibular component.

Congenital deformed/absent TMJ (ie, hemifacial microsomia)

There are hundreds of congenital syndromes that can cause facial deformities. Hemifacial microsomia (HFM) is one of the more common syndromes. Clinical and radiographic features of HFM usually include unilateral hypoplasia or aplasia of the mandibular condyle, ramus, and body as well as hypoplasia of the maxilla, zygomatico-orbital complex, and temporal bone; decreased ipsilateral facial height; retruded mandible with the jaws deviated toward the ipsilateral side; class II malocclusion; transverse cant in the occlusal plane and skeletal structures; significant soft tissue deficiency on the involved side affecting muscles, subcutaneous tissues and skin volume; and decreased oropharyngeal airway (Figs. 19A–D, 20A, C). With growth, the facial deformity, asymmetry, and malocclusion worsen.

A patient with HFM who is 6 to 12 years old with absence of the TMJ may benefit from a growth center transplant using a sternoclavicular graft or rib graft. Rib grafts are unpredictable relative to growth and stability. Sternoclavicular grafts tend to have better growth potential, similar to normal TMJ growth. Orthognathic surgery may be necessary at a later age (following completion of growth) to maximize the functional and aesthetic results. Teenage or older patients with significant deformity of the condyle and ramus may have a much better outcome using a patient-fitted TMJ total joint prosthesis (TMJ Concepts system, Fig. 4) to advance and lengthen the ramus on the ipsilateral side. Deferring treatment until the patient is closer to completion of facial growth (girls, 15 years old; boys, 17–18 years old) helps minimize subsequent contralateral normal growth effect on the treatment outcome. A mandibular ramus sagittal split osteotomy can be performed on the contralateral side, and the indicated maxillary osteotomies can be completed as well as any other adjunct procedures (see Figs. 19E–H; 20B). Additional reconstruction may be necessary using bone grafts, synthetic bone, or alloplastic implants to build up the residual deformed skeletal structures. Soft tissue reconstruction using fat grafts, tissue flaps, and vascularized free flaps, for example, may be necessary to fill out the soft tissue defects.

Connective tissue and autoimmune diseases

Connective tissue/autoimmune diseases that can affect the TMJs include rheumatoid arthritis, juvenile rheumatoid arthritis, psoriatic arthritis, ankylosing spondylitis, Sjogren syndrome, systemic lupus erythema, scleroderma, and mixed connective tissue disease. Multiple systems are usually involved. Peripheral joints are usually symmetrically inflamed, which causes progressive destruction of articular structures. Facial deformity can occur with involvement of the TMJs. Clinical and radiographic features when the TMJs are involved with condylar resorption include (1) retruded mandible; (2) posterior maxillary vertical hypoplasia, (3) progressive worsening facial and occlusal deformity; (4) high occlusal plane angle; (5) class II occlusion and anterior open bite; and (6) TMJ symptoms, such as noises, pain, and jaw dysfunction (Figs. 21A–D, 22A).

MRI features include the loss of condylar vertical dimension and significant mediolateral narrowing, but the condyles may become broad in the anterior to posterior direction; the articular disc may be in position but surrounded by a pannus (reactive tissue) that eventually destroys the disc but also causes condylar and articular eminence resorption; in more severe cases, the condylar stump may function beneath the remaining articular eminence (see Fig. 22C).

The most predictable treatment of the TMJ affected by connective tissue/autoimmune diseases includes (1) bilateral reconstruction of the TMJs (and, if indicated, advance the mandible) with patient-fitted total joint prostheses (TMJ Concepts system, Fig. 4), (2) coronoidotomies or coronoidectomies if the ramus is significantly advanced or vertically lengthened with the prostheses, (3) autogenous fat graft packed around the prosthesis in the articulation area, and (4) maxillary osteotomies and any additional adjunctive procedures indicated (eg, genioplasty, rhinoplasty, turbinectomies, or septoplasty) (see Figs. 21E–H; 22B). Other techniques that have been advocated for TMJ reconstruction include the use of autogenous tissues such as temporal fascia and muscle flaps, dermal grafts, rib grafts, sternoclavicular grafts, and vertical sliding ramus osteotomy. However, the disease process that created the original TMJ disorder can attack the autogenous tissues used in the TMJ reconstruction, which may cause failure of the grafts. The total joint prosthesis with a fat graft packed around it is a superior technique in terms of elimination of the disease process in the TMJ, improved function and aesthetics, and eliminated or decreased pain. When treating young, growing patients (10 years or older), the total joint prosthesis may still be the best option to eliminate the disease process. However, because there would be no growth potential on the involved side(s) of the mandible, orthognathic surgery may be necessary but can be delayed until the patient has completed most facial growth. Then, double jaw surgery can be performed, including the sagittal

Fig. 19. Case 8. (*A–D*) A 14-year-old girl with (1) left hemifacial microsomia and a repaired left transverse facial cleft; (2) hypoplasia of the left ramus and condyle causing major facial asymmetry; (3) retruded mandible and maxilla; and (4) high occlusal plane angle. The first surgical stage included (1) reconstruction and advancement of the left mandible with TMJ Concepts total joint prosthesis and fat graft with pogonion advancing 18 mm; (2) right sagittal split osteotomy; and (3) multiple maxillary osteotomies. A second surgical stage included a fat graft to the left side of the face and a genioplasty. (*E–H*) The patient was seen 2 years after surgery, with improved facial symmetry and stable skeletal and occlusal results.

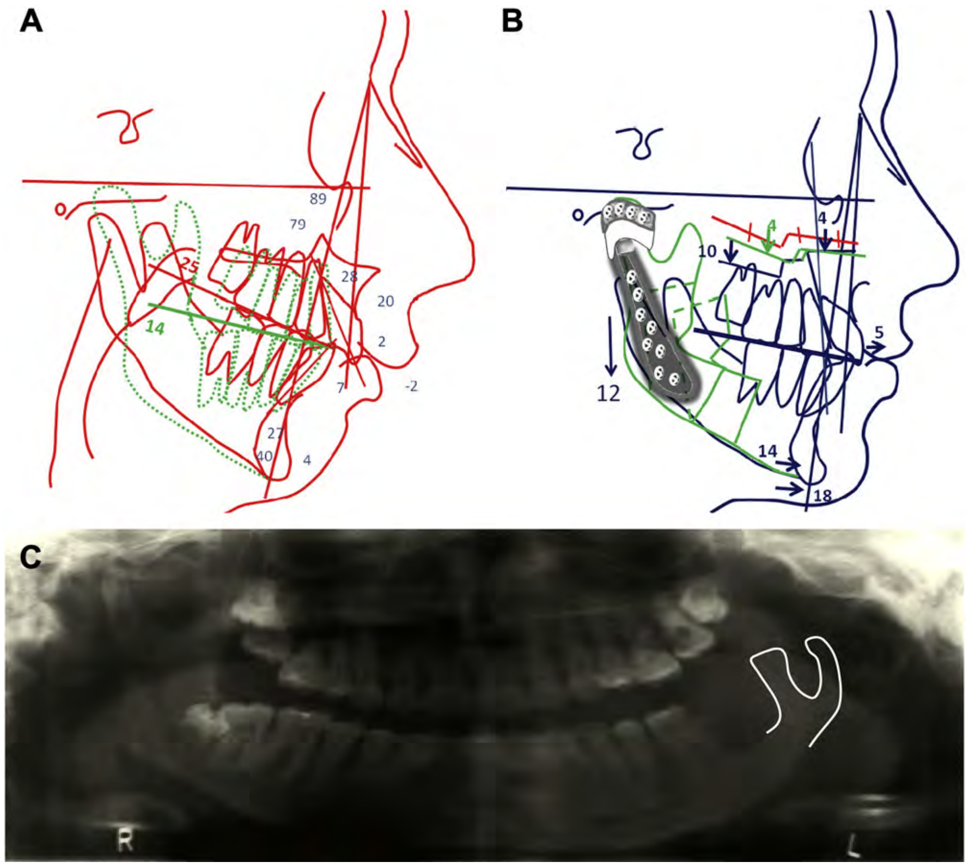

Fig. 20. Case 8. (*A*) Cephalometric tracing shows the retruded maxilla and mandible, vertical asymmetry, and high occlusal plane angle. (*B*) Prediction tracing shows the planned surgical procedures with counterclockwise rotation of the maxillary and mandibular complex with reconstruction of the left TMJ and ramus with a TMJ Concepts total joint prosthesis, right sagittal split osteotomy, and maxillary osteotomies, with pogonion advancing 18 mm. (*C*) The deformed left ramus with evidence of previous attempted autogenous reconstruction.

split on the side of the prosthesis to reposition the jaws into the best alignment, repositioning the mandibular component of the prosthesis, or manufacturing a new longer mandibular component to advance the mandible.

Other end-stage TMJ disorders

Other TMJ end-stage conditions include (1) advanced reactive arthritis, osteoarthritis; (2) neoplasms; (3) joints with multiple operations; (4) failed TMJ alloplastic implants; and (5) failed autogenous tissue TMJ reconstruction. Patients with these TMJ disorders may benefit from TMJ reconstruction and mandibular repositioning with total joint prosthesis (TMJ Concepts system, Fig. 4) and placement of fat grafts around the articulating part of the prostheses, as well as simultaneous maxillary osteotomies and other indicated adjunctive procedures to achieve the best outcome results relative to function, stability, aesthetics, and elimination of pain.

Our studies show good outcomes with this treatment protocol. However, the quality of results decreases as the number of previous TMJ surgeries increases, particularly in reference to pain relief. When the TMJ Concepts total joint prostheses system is used as the first or second TMJ surgery, the success rate is very good in terms of jaw function, stability, facial balance, and pain relief.

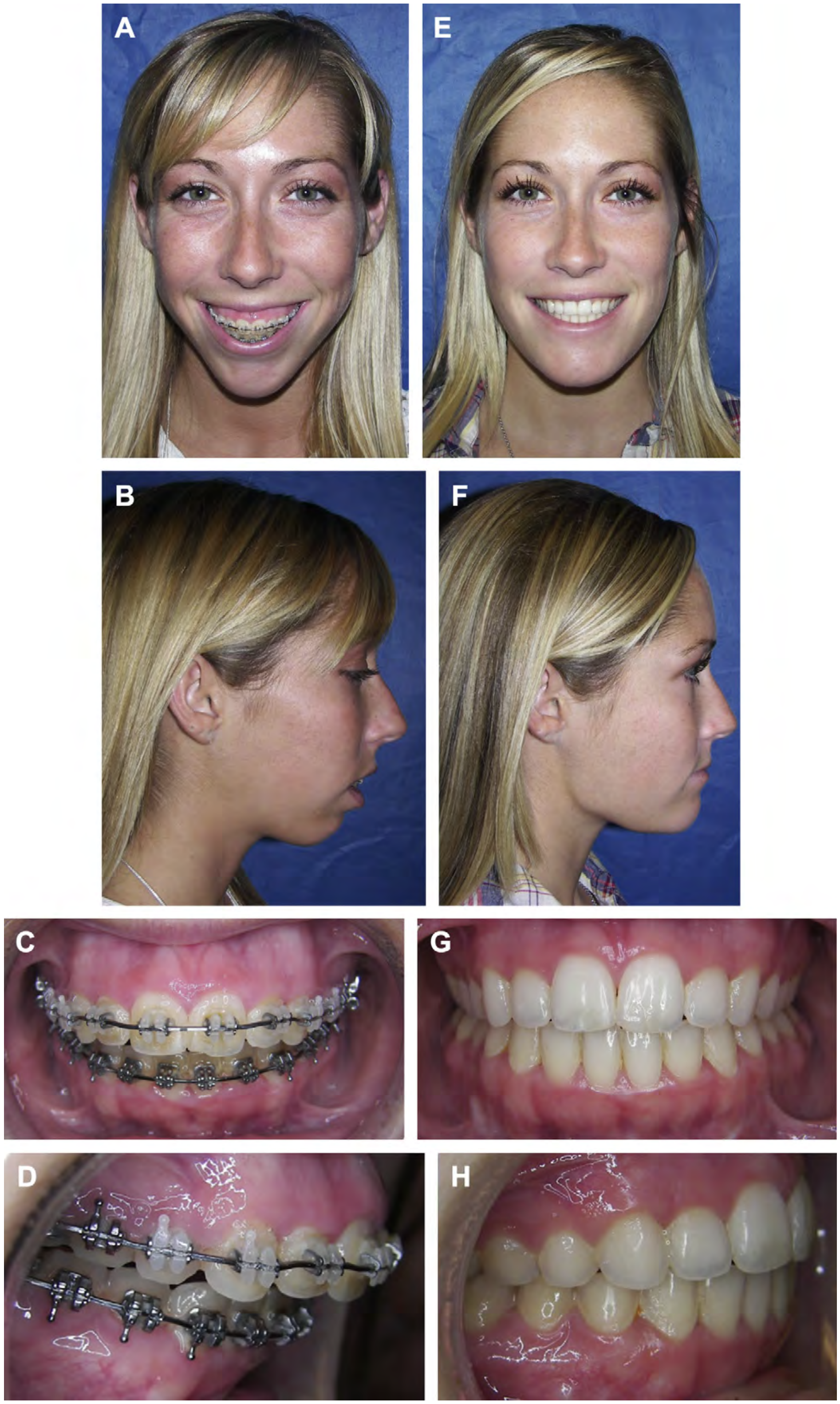

Fig. 21. Case 9. (*A–D*) A 21-year-old woman diagnosed with (1) juvenile rheumatoid arthritis with onset at age 12 years, (2) severe condylar resorption, (3) retruded maxilla and mandible, (4) class II end-on occlusion with anterior open bite, (5) hypertrophied turbinates, (6) severe TMJ pain, and (7) sleep apnea. Single-stage surgery included (1) bilateral TMJ reconstruction and mandibular counterclockwise advancement with TMJ Concepts total joint prostheses and genioplasty with pogonion advancing 19 mm; (2) maxillary osteotomies; (3) coronoidotomies; (4) turbinectomies; and (5) fat grafts, harvested from the abdomen, packed around the prostheses. (*E–H*) The patient was seen 2.5 years after surgery, pain free with a good functional and aesthetic outcome.

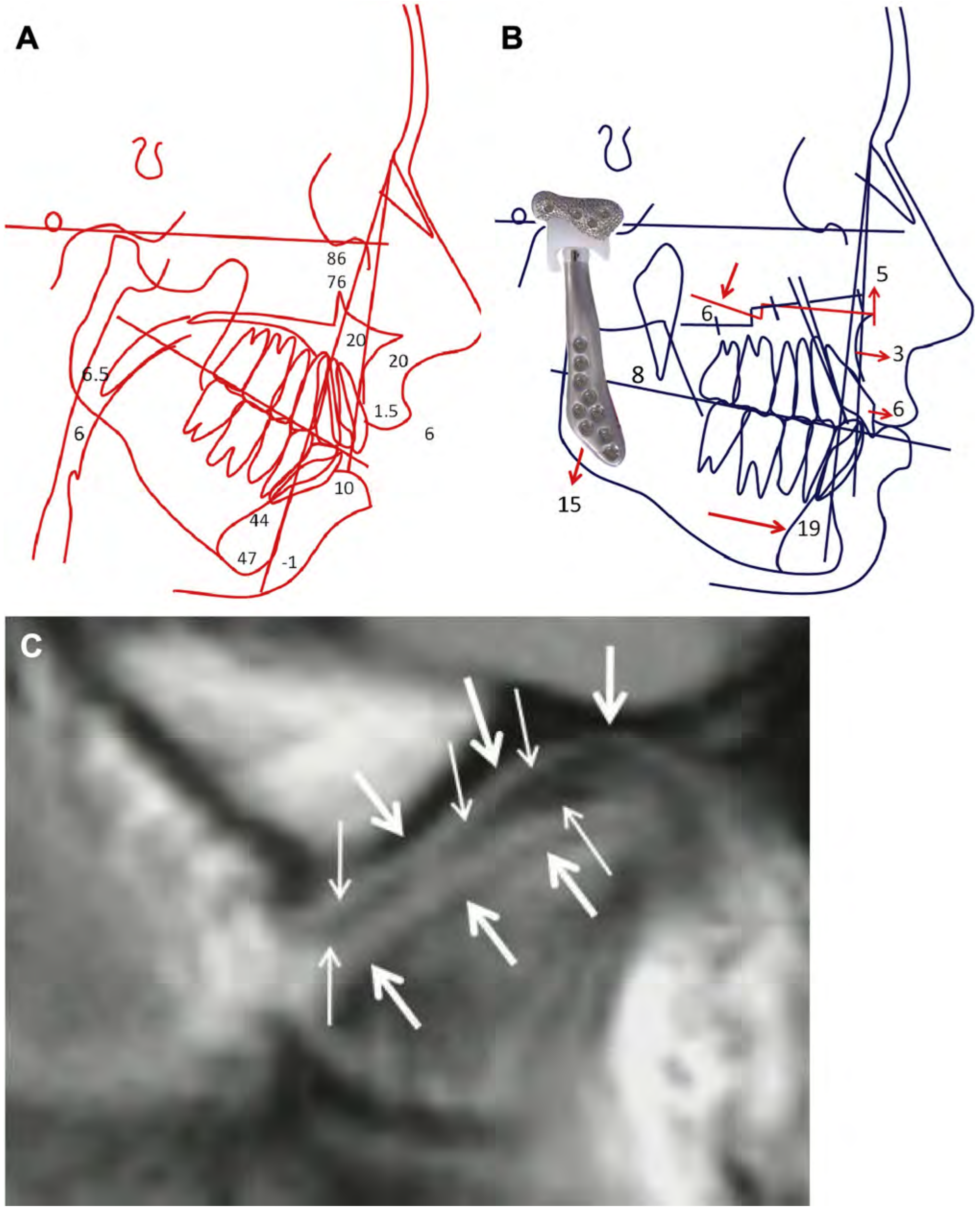

Fig. 22. Case 9. (*A*) Cephalometric analysis shows retruded mandible and maxilla, high occlusal plane angle, and class II open bite. (*B*) Prediction tracing shows mandibular counterclockwise rotation with TMJ Concepts total joint prostheses, maxillary osteotomies, and genioplasty with pogonion advancing 19 mm. (*C*) MRI of juvenile rheumatoid arthritis shows severe condylar resorption (thick arrows outline the condyle and fossa), articular eminence resorption, and shows the disc (*thin arrows*) in normal position, but surrounded by a reactive pannus that causes destruction of the disc, condyle, and the articular eminence.

Summary

Healthy and stable TMJs are necessary for quality treatment outcomes in orthognathic surgery. If the TMJs are not stable and healthy, orthognathic surgery results may be unsatisfactory relative to function, aesthetics, skeletal and occlusal stability, and pain. The oral and maxillofacial surgeon should be suspicious of possible TMJ problems in (1) patients with class II high occlusal plane angle and retruded mandibular morphologic type, particularly those with anterior open bites; (2) patients with progressively worsening class II occlusal and jaw relationship; (3) patients with class III prognathism that progressively worsens; (4) patients with facial asymmetry, particularly with progressive worsening; and (5) patients reporting headaches, TMJ pain, myofascial pain, clicking and popping of the TMJs, and/or ear symptoms. With 1 or more of these symptoms, patients should be evaluated for possible TMJ disorders; the surgeon should not ignore these symptoms. An MRI of the TMJs can aid in identifying the specific TMJ disorder. Failure to recognize and treat these conditions can result in significant relapse, increased pain, and more complex treatment.

During the past 2 decades, major advancements have been made in TMJ diagnostics and the development of surgical procedures that treat and rehabilitate the pathologic, dysfunctional, and painful TMJ. Research has clearly shown that TMJ and orthognathic surgery can be safely and predictably performed at the same operation, but the correct diagnosis and treatment plan is required and the surgeon must have expertise in both TMJ and orthognathic surgery. The surgical procedures can be separated into 2 or more surgical stages, but the TMJ surgery should be done first. With the correct diagnosis and treatment plan, combined TMJ and orthognathic surgical approaches provide complete and comprehensive management of patients with coexisting TMJ disorders and dentofacial deformities.

Further readings

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